NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 827

CHARTS FOR THE MINIMUM-WEIGHT DESIGN OF 24S-T ALUMINUM-ALLOY FLAT COMPRESSION PANELS WITH LONGITUDINAL Z-SECTION STIFFENERS

By EVAN H. SCHUETTE

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AERONAUTIC SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Abbreviation	Unit	Abbreviation
Length	l	meter	m	foot (or mile)	ft (or mi)
Time	t	second	s	second (or hour)	sec (or hr)
Force	F	weight of 1 kilogram	kg	weight of 1 pound	lb
Power	P	horsepower (metric)		horsepower	hp
Speed	V	{kilometers per hour / meters per second}	kph / mps	miles per hour / feet per second	mph / fps

2. GENERAL SYMBOLS

W Weight $=mg$

g Standard acceleration of gravity $=9.80665$ m/s² or 32.1740 ft/sec²

m Mass $=\frac{W}{g}$

I Moment of inertia $=mk^2$. (Indicate axis of radius of gyration k by proper subscript.)

μ Coefficient of viscosity

ν Kinematic viscosity

ρ Density (mass per unit volume)

Standard density of dry air, 0.12497 kg-m^{-4}-s^2 at 15° C and 760 mm; or 0.002378 lb-ft^{-4} sec^2

Specific weight of "standard" air, 1.2255 kg/m³ or 0.07651 lb/cu ft

3. AERODYNAMIC SYMBOLS

S Area

S_w Area of wing

G Gap

b Span

c Chord

A Aspect ratio, $\frac{b^2}{S}$

V True air speed

q Dynamic pressure, $\frac{1}{2}\rho V^2$

L Lift, absolute coefficient $C_L=\frac{L}{qS}$

D Drag, absolute coefficient $C_D=\frac{D}{qS}$

D_0 Profile drag, absolute coefficient $C_{D_0}=\frac{D_0}{qS}$

D_i Induced drag, absolute coefficient $C_{D_i}=\frac{D_i}{qS}$

D_p Parasite drag, absolute coefficient $C_{D_p}=\frac{D_p}{qS}$

C Cross-wind force, absolute coefficient $C_C=\frac{C}{qS}$

i_w Angle of setting of wings (relative to thrust line)

i_t Angle of stabilizer setting (relative to thrust line)

Q Resultant moment

Ω Resultant angular velocity

R Reynolds number, $\rho\frac{Vl}{\mu}$ where l is a linear dimension (e.g., for an airfoil of 1.0 ft chord, 100 mph, standard pressure at 15° C, the corresponding Reynolds number is 935,400; or for an airfoil of 1.0 m chord, 100 mps, the corresponding Reynolds number is 6,865,000)

α Angle of attack

ϵ Angle of downwash

α_0 Angle of attack, infinite aspect ratio

α_i Angle of attack, induced

α_a Angle of attack, absolute (measured from zero-lift position)

γ Flight-path angle

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SUMMARY

Design charts are developed for 24S–T aluminum-alloy flat compression panels with longitudinal **Z**-*section stiffeners. These charts make possible the design of the lightest panels of this type for a wide range of design requirements. Examples of the use of the charts are given and it is pointed out on the basis of these examples that, over a wide range of design conditions, the maintenance of buckle-free surfaces does not conflict with the achievement of high structural efficiency. The achievement of the maximum possible structural efficiency with 24S–T aluminum-alloy panels, however, requires closer stiffener spacings than those now in common use.*

INTRODUCTION

In a longitudinally stiffened compression panel, in which all the material is active in carrying load, the requirement of minimum weight is tantamount to that of carrying the load at the highest possible average stress. The average stress developed by such a panel under the loading conditions imposed is thus a direct measure of the structural efficiency of the panel. If longitudinally stiffened compression panels are to be designed for high structural efficiency without a large number of cut-and-try computations, it is desirable that design charts be prepared to indicate the average stress attainable under various loading conditions. The preparation of such charts requires that a suitable design parameter in which the important loading conditions are incorporated be found.

It has been found that a suitable parameter for longitudinally stiffened compression panels in the design of which the transverse stiffness can be neglected is $\frac{P_t}{L/\sqrt{c}}$, where P_t is the compressive load per inch of panel width, L is the panel length, or distance between supporting ribs, and c is the coefficient of end fixity at the ribs. The quantity P_t, which is essentially independent of the distribution of material in the compression panel, can be estimated for a wing panel from the bending moment on the wing and the thickness and chord of the wing. The length L may be fixed by the presence of such installations as fuel tanks or armament or may be arbitrarily assigned for the purpose of arriving at a trial design.

In reference 1 buckling stresses were plotted against the parameter $\frac{P_t}{L/\sqrt{c}}$, with slightly different notation, to form the basis of a theoretical study of the efficiencies of various types of stiffening elements. In the present paper the same parameter has been used as a basis for the preparation of design charts from extensive test data on 24S–T aluminum-alloy flat compression panels with longitudinal **Z**-section stiffeners; the data were obtained from reference 2 and from additional tests completed since publication of reference 2. These charts make possible the choice of the lightest panels of this type to conform to a wide range of design conditions. An appendix is presented in which the procedure followed in preparing the charts from test data is described and the method for obtaining $\frac{P_t}{L/\sqrt{c}}$ as a natural parameter against which the average stress may be plotted to obtain a direct measure of structural efficiency is developed.

SYMBOLS AND DEFINITIONS

The symbols used for the principal panel cross-sectional dimensions are indicated in figure 1. In addition, the following symbols are used:

- A_t cross-sectional area per inch of panel width, or equivalent thickness of panel, inches
- L length of panel, inches
- P_t compressive load per inch of panel width, kips per inch
- E_c modulus of elasticity in compression, ksi
- c coefficient of end fixity as used in Euler column formula
- k coefficient in formula for local-buckling stress
- ρ radius of gyration of panel cross section, inches
- τ nondimensional coefficient that takes into account reduction in effective modulus of elasticity when panel fails as a column beyond the elastic range
- σ_{cr} critical stress, or stress for local buckling, ksi
- $\bar{\sigma}_c$ average stress at column failure, ksi
- $\bar{\sigma}_{max}$ average stress at local failure, ksi
- $\bar{\sigma}_f$ average stress at failure for any panel, ksi

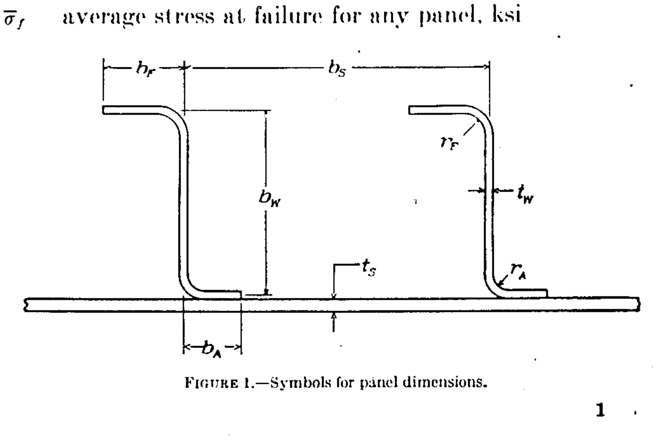

FIGURE 1.—Symbols for panel dimensions.

The average stress at which any particular panel fails, $\bar{\sigma}_f$, may be a local-failure stress, a column-failure stress, or the stress for a type of failure intermediate to these two. Failure by twisting of the stiffeners is included as a form of local failure. Because the design charts are based on actual test data, it is not necessary to make any distinction between local and twisting failure. Such a distinction, moreover, would be at best an arbitrary one, as the two types of failure are interrelated in the case of stiffened panels.

It should be noted that the local-failure stress $\bar{\sigma}_{max}$, which represents the maximum value of average stress that can be achieved in a given cross section as the panel length is reduced, is an average stress at *failure* and is not to be confused with the stress for local *buckling* σ_{cr}, which does not necessarily imply failure. The term "local buckling" as used herein includes both buckling of the skin and buckling of the stiffeners, because neither of these elements can buckle without exerting moments on, and thus causing deformation of, the other element.

DESIGN CHARTS

Design charts for 24S–T aluminum-alloy flat compression panels with longitudinal **Z**-section stiffeners are presented in figures 2 to 5. The procedure used in the preparation of these charts from test data is described in the appendix. Values of A_i/t_S, necessary for arriving at a final design, are given in tables 1 to 3 for a wide range of dimension ratios.

In order to show the maximum stresses attainable by the use of panels of the type to which the charts apply, envelopes are indicated by the dashed lines for each value of the ratio b_S/t_S in figures 2 to 5. These envelopes have been combined (fig. 6) to give the over-all envelopes for the four values of the ratio t_W/t_S. The values of b_S/t_S and b_W/t_W needed in order that a panel will develop the stress indicated by an envelope are also given in figure 6.

The design parameter $\frac{P_i}{L/\sqrt{c}}$, against which stress is plotted in figures 2 to 6, comprises the principal design conditions: the compressive load per inch of panel width; the length of panel, or distance between supporting ribs; and the coefficient of end fixity. The most efficient (lightest) panel for a given combination of these conditions is that panel which will develop the highest average stress for the particular value of $\frac{P_i}{L/\sqrt{c}}$.

Discussion of charts.—The charts include a wide range of panel proportions. All the charts have been drawn for a value of $\frac{b_F}{b_W}=0.4$; it is shown in the appendix (figs. 17 to 20), however, that curves for $\frac{b_F}{b_W}=0.3$ and 0.5 would be in close agreement with the curves for $\frac{b_F}{b_W}=0.4$. The curves of figures 2 to 5 may therefore be applied with reasonable accuracy for any value of b_F/b_W between 0.3 and 0.5. The available test data seem to indicate, moreover, that the most efficient use of material will be realized if a proportion in this range is selected. (See appendix.)

The short horizontal lines that intersect the curves of figures 2 to 5 indicate, for each panel cross section having appreciable local buckling, the stress at which this buckling occurs. In this report this stress is taken as that at which the compressive strain on one side of the skin or the stiffener web begins to be reduced with increasing load. This definition of buckling is convenient for structural testing; from the standpoint of aerodynamic smoothness, appreciable buckling probably takes place at stresses somewhat lower than those indicated on the charts. It will be noted that for some of the lower values of b_S/t_S and b_W/t_W no buckling stress is shown. In these cases, there will undoubtedly be some buckling but presumably it will occur at a stress coincident with or only very slightly below the failure stress.

It is pointed out that for $\frac{t_W}{t_S}=0.79$ and 1.00 (figs. 4 and 5), the curves for values of $\frac{b_S}{t_S}=25$ and 30 have been obtained entirely by extrapolation. These curves should therefore be used with a certain degree of caution. A few check tests made since the preparation of the charts, however, indicate that the curves will in no case be more than 6 percent unconservative. In all the other curves, it is believed that any unconservatism that may be present is of much smaller magnitude.

Discussion of tests and test panels.—In order that the design charts may be properly used, it is necessary to know something of the test panels and the test results on which the design charts are based. The details of these tests are described in reference 2; some of the pertinent information regarding the tests follows:

The test panels consisted of six stiffeners and five bays. The panels were tested flat-ended and without edge support. A fixity coefficient of 3.75 was used in reducing the test data for application to an effective pin-ended length. The average compressive yield strength for the material of which the test panels were constructed was about 44 ksi; the minimum yield strength, about 41 ksi; and the maximum yield strength, about 46.5 ksi. The rivets were countersunk and were driven by the NACA method of inserting a flat-head rivet from the stiffener side of the hole, upsetting the rivet shank into the countersunk cavity, and milling off the protruding portion of the upset shank. The rivets were A17S–T (AN442AD) and were of the sizes and spacings indicated by the following table:

$\frac{t_W}{t_S}$	$\frac{\text{Rivet spacing}}{t_S}$	$\frac{\text{Rivet diameter}}{t_S}$
0.51	10.0	1.50
.63	12.3	1.84
.79	12.3	1.93
1.00	11.7	1.95

Because the compressive strength of stiffened panels may be affected by the size and spacing of the rivets used to attach stiffeners to skin (reference 3), the rivet attachment must be equivalent to that indicated by the foregoing table in order to be sure of realizing the strengths indicated by the design charts.

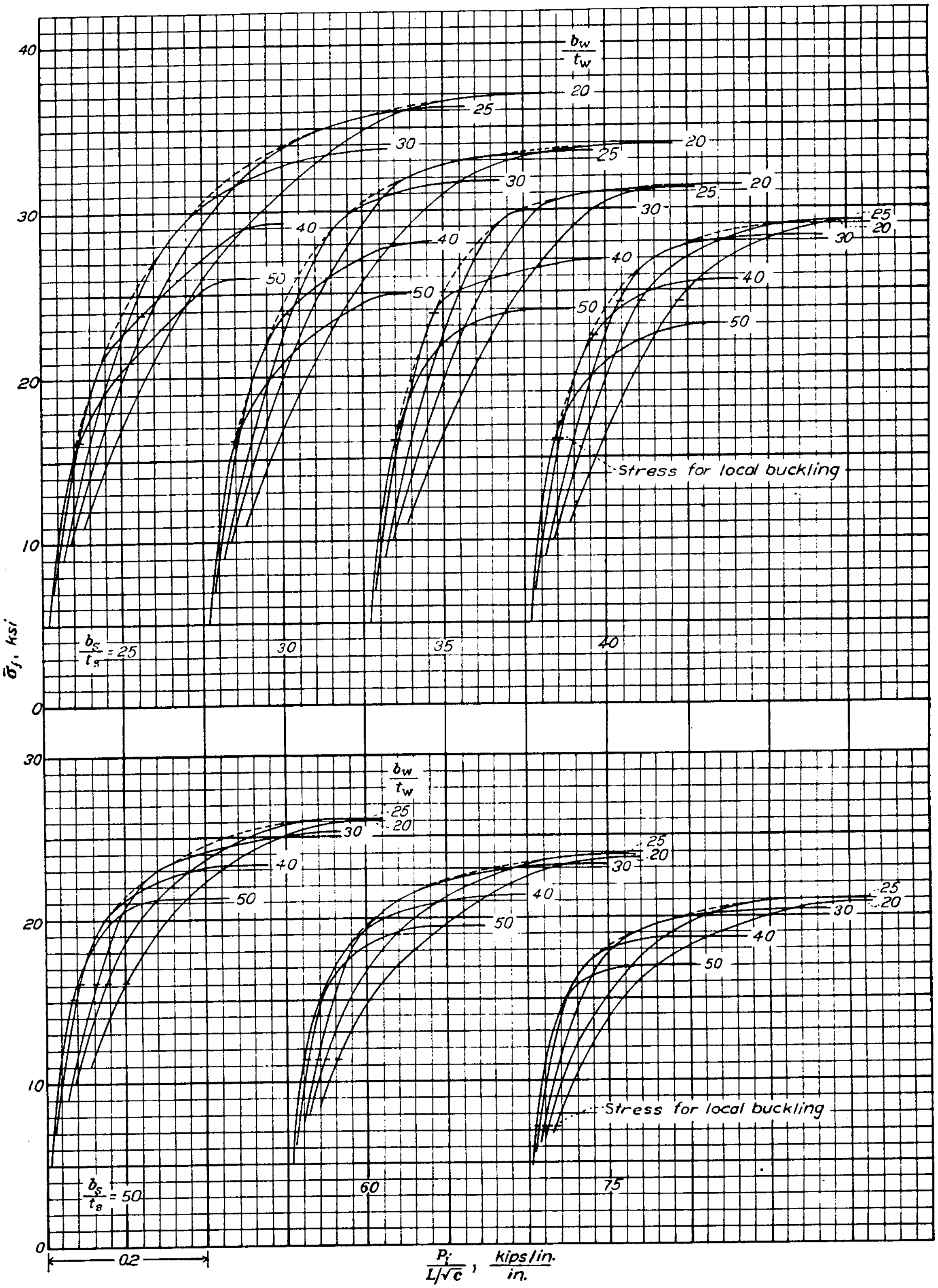

FIGURE 2.—Design chart for 24S-T aluminum-alloy flat panels with Z-section stiffeners; $\frac{t_W}{t_S}=0.51$ $\left(\frac{b_A}{t_W}=11.4;\ \frac{r_A}{t_W}=3;\ \frac{r_F}{t_W}=4;\ \text{and}\ \frac{b_F}{b_W}=0.3\ \text{to}\ 0.5\right)$.

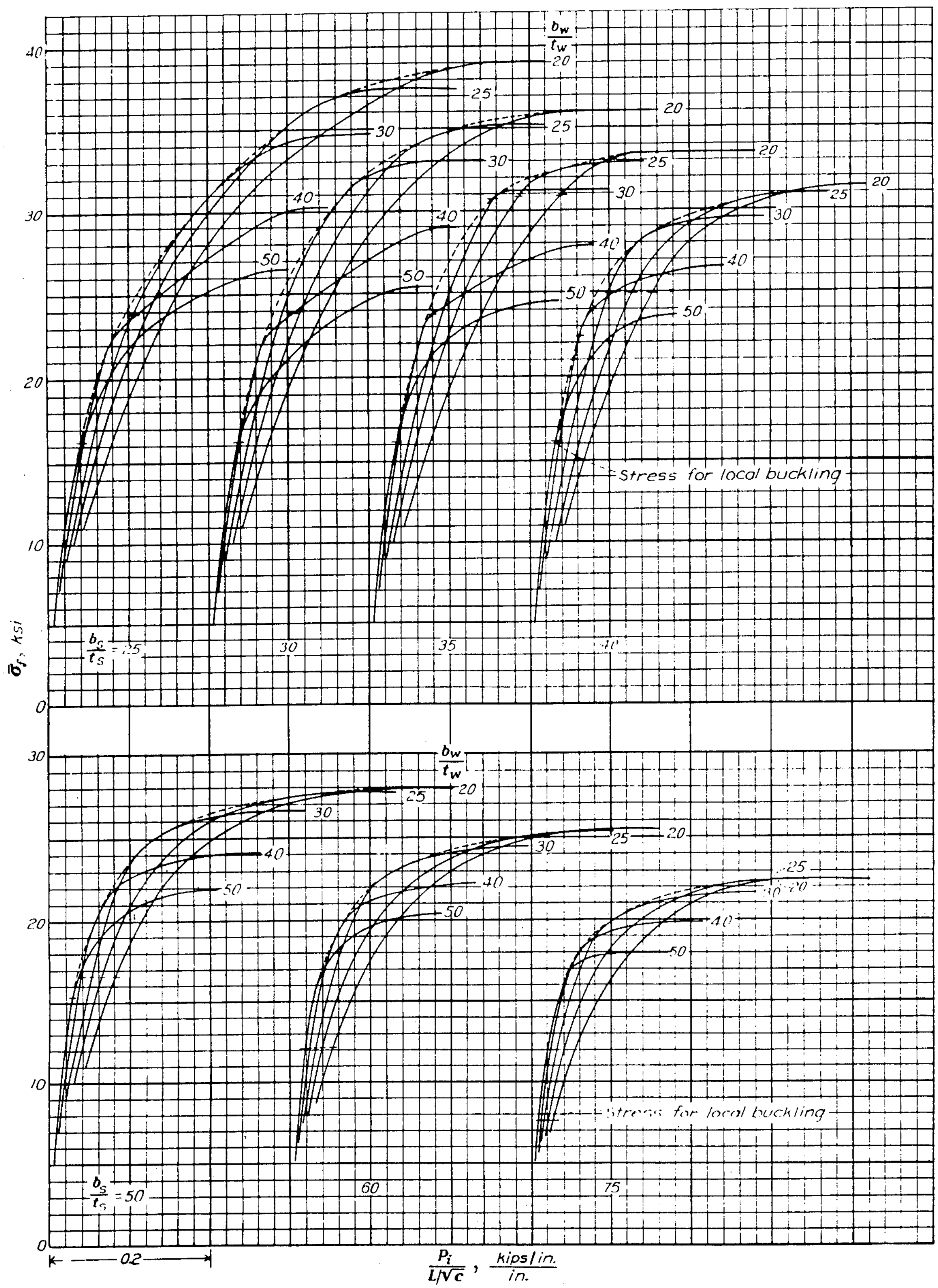

FIGURE 3.—Design chart for 24S-T aluminum-alloy flat panels with Z-section stiffeners; $\frac{t_W}{t_S}=0.63$ $\left(\frac{b_A}{t_W}=10.9;\ \frac{r_A}{t_W}=3;\ \frac{r_F}{t_W}=4;\text{ and }\frac{b_F}{b_W}=0.3\text{ to }0.5\right)$.

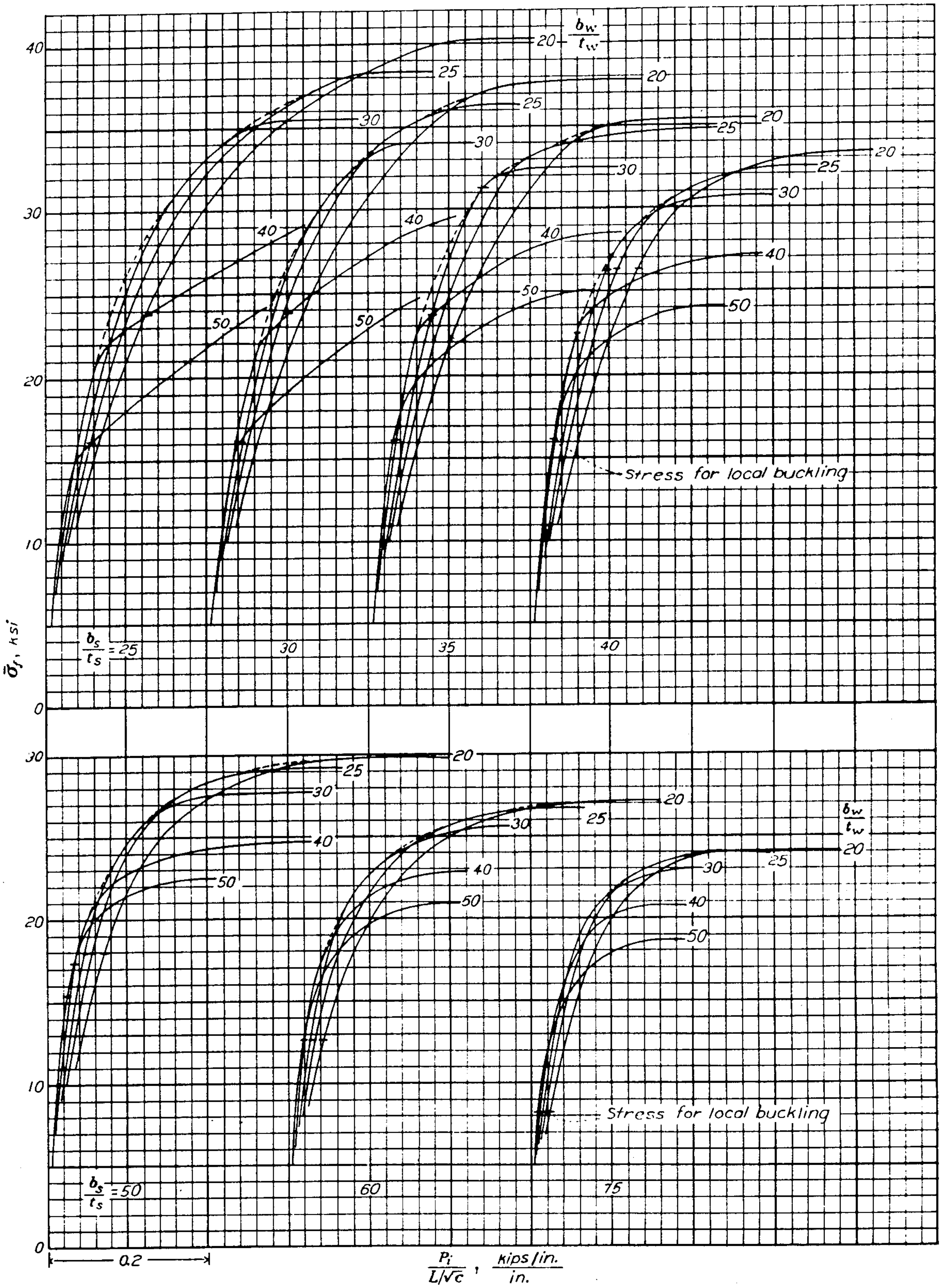

FIGURE 4.—Design chart for 24S-T aluminum-alloy flat panels with Z-section stiffeners: $\frac{t_W}{t_S}=0.79$ $\left(\frac{b_A}{t_W}=9.8;\ \frac{r_A}{t_W}=3;\ \frac{r_F}{t_W}=4;\ \text{and}\ \frac{b_F}{b_W}=0.3\ \text{to}\ 0.5\right)$.

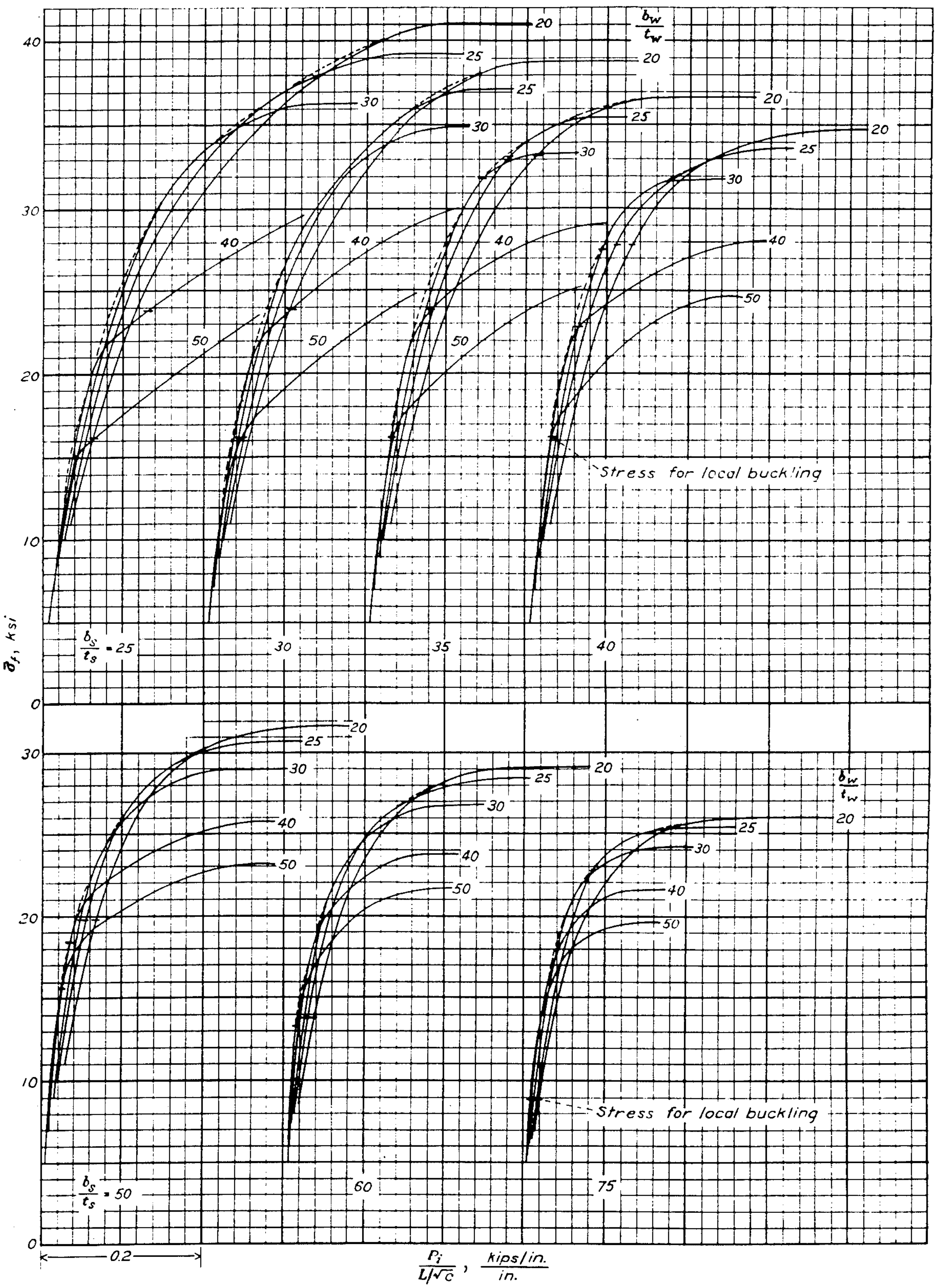

FIGURE 5.—Design chart for 24S-T aluminum-alloy flat panels with Z-section stiffeners; $\frac{t_W}{t_S}=1.00$ $\left(\frac{b_A}{t_W}=8.6;\ \frac{r_A}{t_W}=3;\ \frac{r_F}{t_W}=4;\ \text{and}\ \frac{b_F}{b_W}=0.3\ \text{to}\ 0.5\right)$.

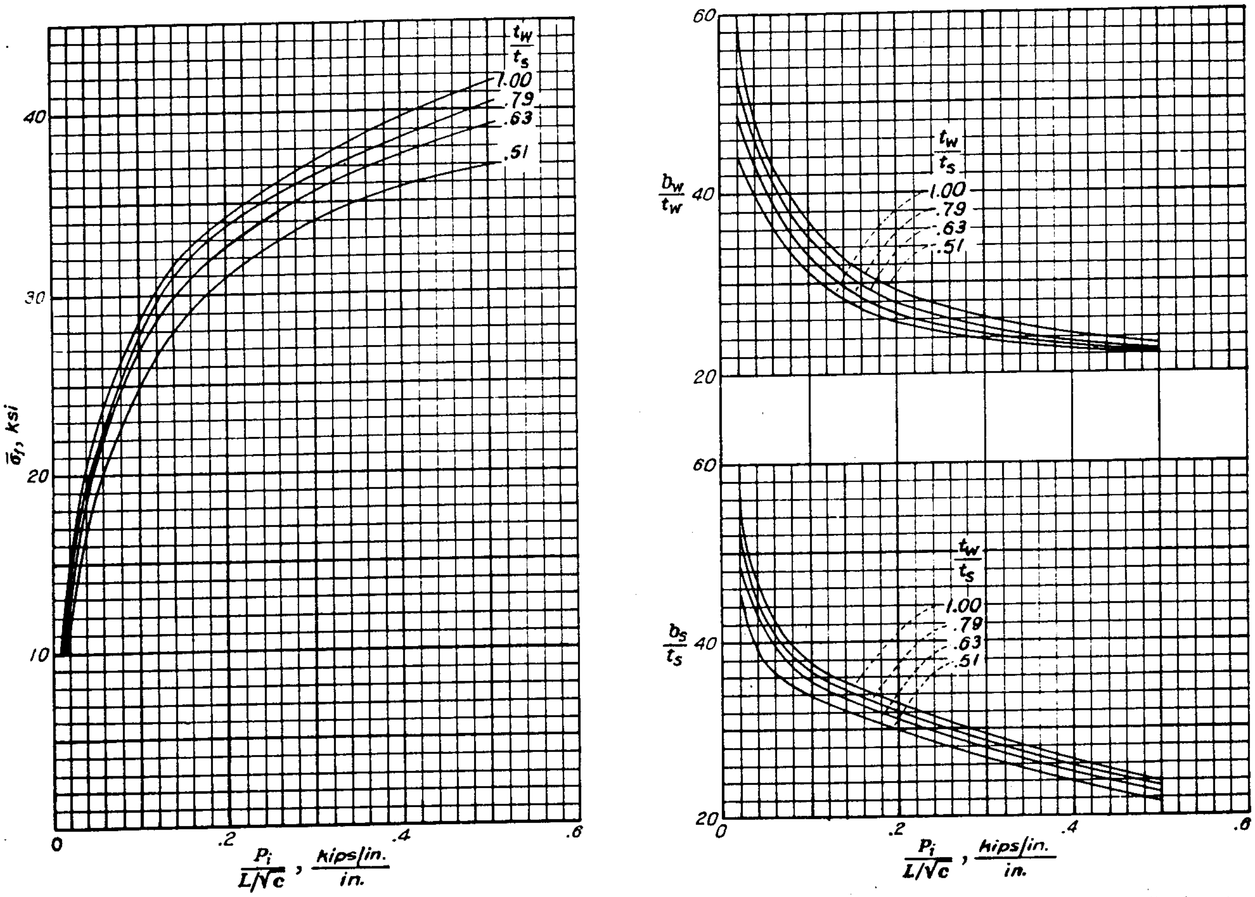

FIGURE 6.—Highest values of average stress at failure for 24S-T aluminum-alloy flat panels with Z-section stiffeners, with values of b_S/t_S and b_W/t_W needed to realize these stresses.

USE OF DESIGN CHARTS AND EXAMPLES

If sheet material could be obtained in any desired thickness and if no special limitations were put on the design, it would be sufficient merely to find those proportions that would give the highest stress for the given value of $\frac{P_i}{L/\sqrt{c}}$. Because certain limitations are usually imposed, however, the structure that represents the best compromise of all the requirements must be chosen.

The usual gages in which aluminum-alloy sheet is manufactured are such that if the four ratios of t_W/t_S in figures 2 to 6 are applied consecutively to a particular skin gage, the four stiffener gages that result will generally be consecutive standard gages. Interpolation between the curves of two consecutive charts (figs. 2 and 3, 3 and 4, etc.) is therefore unnecessary for most practical purposes.

The particular procedure to be used in obtaining a design from the charts will depend on the nature of the results desired. Three possible methods are discussed, and examples are given of designs obtained for a given load intensity and three different lengths by each of the methods.

The distinguishing features of each method are

Ideal design:

The method for obtaining the ideal design gives the lightest panel that could be obtained if the designer were not restricted to the use of standard sheet gages. The design is obtained by use of the over-all envelopes of figure 6 only.

Short method:

The short design method provides, without lengthy computation, a near approach to the lightest panel that can be obtained by use of standard sheet gages. The design is obtained by use of the envelopes for given values of b_S/t_S that appear as dashed lines in figures 2 to 5.

Maximum efficiency:

The method of designing for maximum structural efficiency gives the lightest panel that can be obtained by use of standard sheet gages. The design is obtained through a complete study of the individual solid curves in figures 2 to 5. The method is somewhat lengthy; examples have been worked out by its use, however, to serve as a check on the short method, so that that method can be used with confidence.

Each of the three methods is given as a series of steps for reaching the final designs. In the method for obtaining the ideal design, the detailed computations for the four values of t_W/t_S included in figure 6 are given for $L=10$, 20, and 30 inches with $P_i=3.0$ kips per inch and $c=1$. In the other two methods, the detailed computations are given only for $L=20$ inches and $\frac{t_W}{t_S}=0.79$, again with $P_i=3.0$ kips per inch and $c=1$; final results are given, however, for the complete set of examples considered in the discussion of the first method. It is assumed in all cases that a skin thickness of 0.064 inch is necessary in order to comply with other design requirements. A value of b_F/b_W of 0.4 is used throughout. In arriving at the final designs, no values of the dimension ratios outside of the ranges covered by the charts are given consideration.

Method for obtaining the ideal design.—The ideal-design method consists of picking from figure 6 the optimum proportions and the stress and computing from these the actual panel dimensions.

The values and computed quantities for the conditions previously mentioned are given in table 4 and are referenced to the steps in the following procedure:

(1) Compute $\frac{P_i}{L/\sqrt{c}}$.

(2) From the curves of figure 6 pick off for each value of t_W/t_S the values of b_S/t_S, b_W/t_W, and $\bar{\sigma}_f$ corresponding to the value of $\frac{P_i}{L/\sqrt{c}}$.

(3) Pick from table 2 the values of A_i/t_S for the ratios determined in step 2. (If $\frac{b_F}{b_W}=0.3$ or 0.5 is used, table 1 or table 3, respectively, should be used instead of table 2.)

(4) Compute

$$t_S=\frac{P_i}{\bar{\sigma}_f \frac{A_i}{t_S}}$$

This formula is based on the equality

$$P_i=\bar{\sigma}_f A_i$$

(5) Compute

$$t_W=\frac{t_W}{t_S}\, t_S$$

$$b_S=\frac{b_S}{t_S}\, t_S$$

$$b_W=\frac{b_W}{t_W}\, t_W$$

This procedure results in four designs for each length, corresponding to the four values of t_W/t_S, for the given conditions. (See table 4.) The values marked with footnote *a* in table 4 represent those chosen as approaching most closely the desired condition of $t_S=0.064$ inch; these values therefore give an indication of the proportions needed in a practical design to meet the design requirements most efficiently.

The resulting designs are shown as the ideal designs at the tops of figures 7 to 9, along with bar graphs of the average stress at failure and the buckling stress. The buckling stress for each design was obtained by interpolation from the short horizontal lines for buckling in figures 2 to 5. In some cases in which failure is by column action, the buckling stress shown by figures 2 to 5 will be greater than the failure stress for the designs obtained. Whenever this difference occurred in the present examples, the buckling stress is shown equal to the failure stress.

Short method for obtaining a practical design.—The short method consists of picking the optimum value of b_W/t_W and the corresponding stress for each value of b_S/t_S from the individual envelopes of figures 2 to 5 and computing from these values the actual panel dimensions. Panel designs that employ standard sheet gages are then selected from the various designs obtained.

The values and computed quantities for $L=20$ inches and $\frac{t_W}{t_S}=0.79$ are given in table 5 and are referenced to the steps in the following procedure:

(1) Compute $\frac{P_i}{L/\sqrt{c}}$.

(2) From the curves for a particular value of t_W/t_S (in this example, fig. 4 for $\frac{t_W}{t_S}=0.79$ is used) pick off for each value of b_S/t_S the values of b_W/t_W (by interpolation along the dashed envelope) and $\bar{\sigma}_f$ (from the envelope) corresponding to the value of $\frac{P_i}{L/\sqrt{c}}$.

(3) Pick from table 2 the values of A_i/t_S for the ratios determined in step 2.

(4) Compute

$$t_S=\frac{P_i}{\bar{\sigma}_f \frac{A_i}{t_S}}$$

(5) Plot b_W/t_W, t_S, and $\bar{\sigma}_f$ against b_S/t_S for the particular value of t_W/t_S. (The plot for the example being considered is shown in fig. 10.) Tabulate the values of b_S/t_S, b_W/t_W, and $\bar{\sigma}_f$ corresponding to the point where t_S equals the specified value.

(6) Check computations by picking from table 2 the value of A_i/t_S corresponding to the ratios tabulated in step 5. If all computations and plots are correct,

$$P_i=\bar{\sigma}_f \frac{A_i}{t_S}\, t_S$$

(7) Compute

$$t_W=\frac{t_W}{t_S}\, t_S$$

$$b_S=\frac{b_S}{t_S}\, t_S$$

$$b_W=\frac{b_W}{t_W}\, t_W$$

(8) Repeat steps 2 to 7 for other values of t_W/t_S.

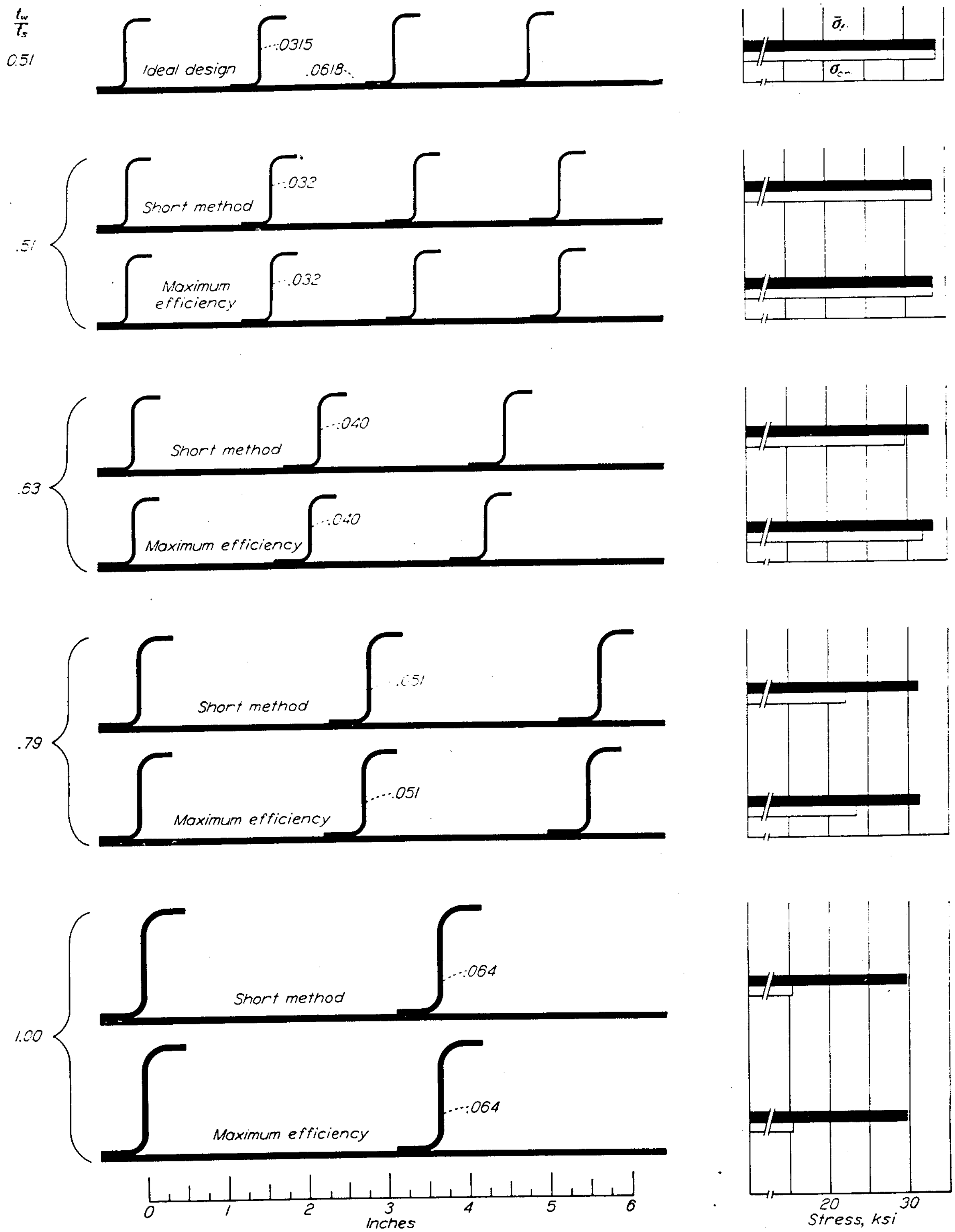

FIGURE 7.—Designs of 24S-T aluminum-alloy panels 10 inches long with P_i=3.0 kips per inch, c=1, and t_S=0.064 inch.

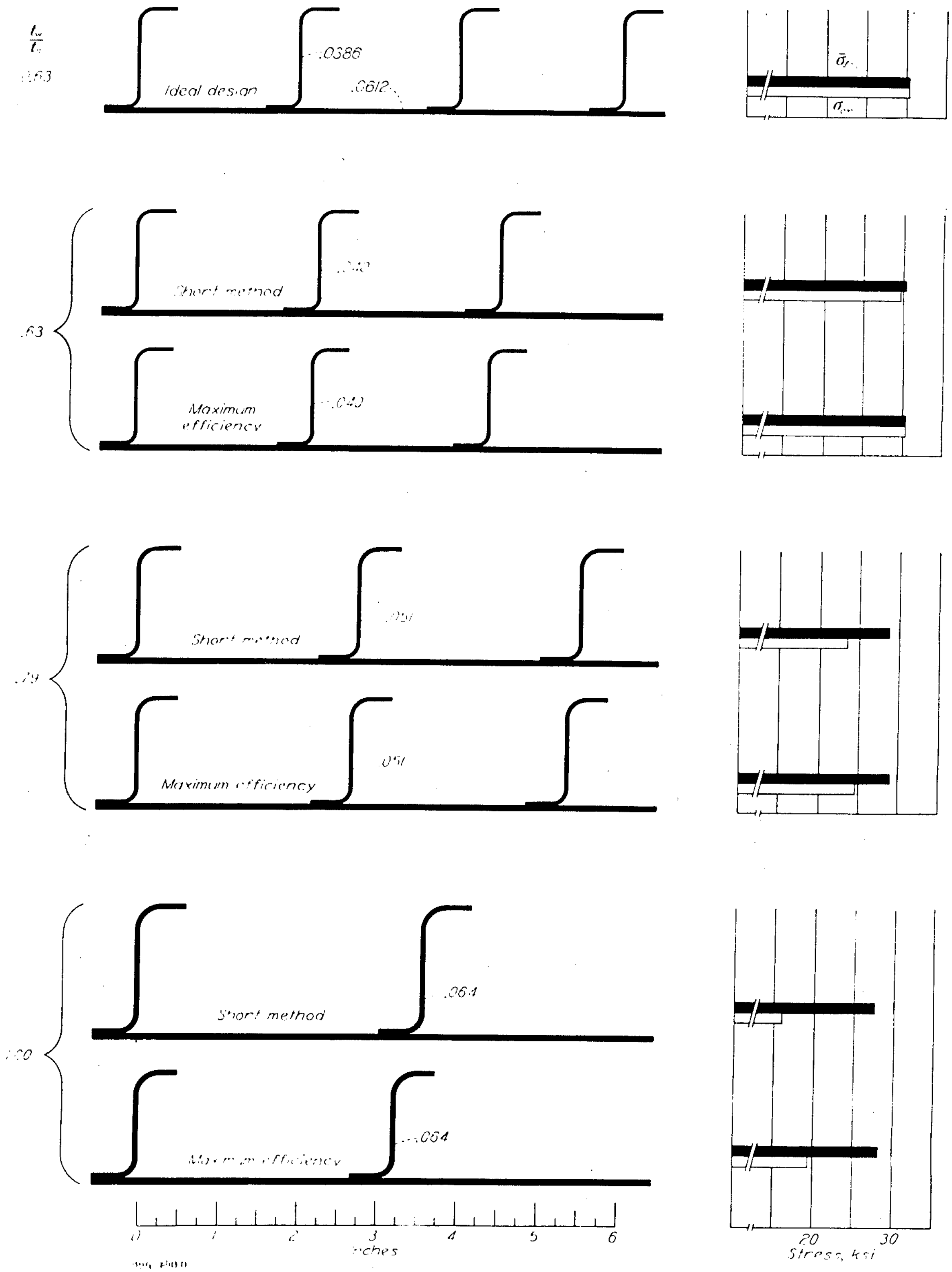

FIGURE 8.—Designs of 24S-T aluminum-alloy panels 20 inches long with P_1=3.0 kips per inch, c=1, and t_s=0.064 inch.

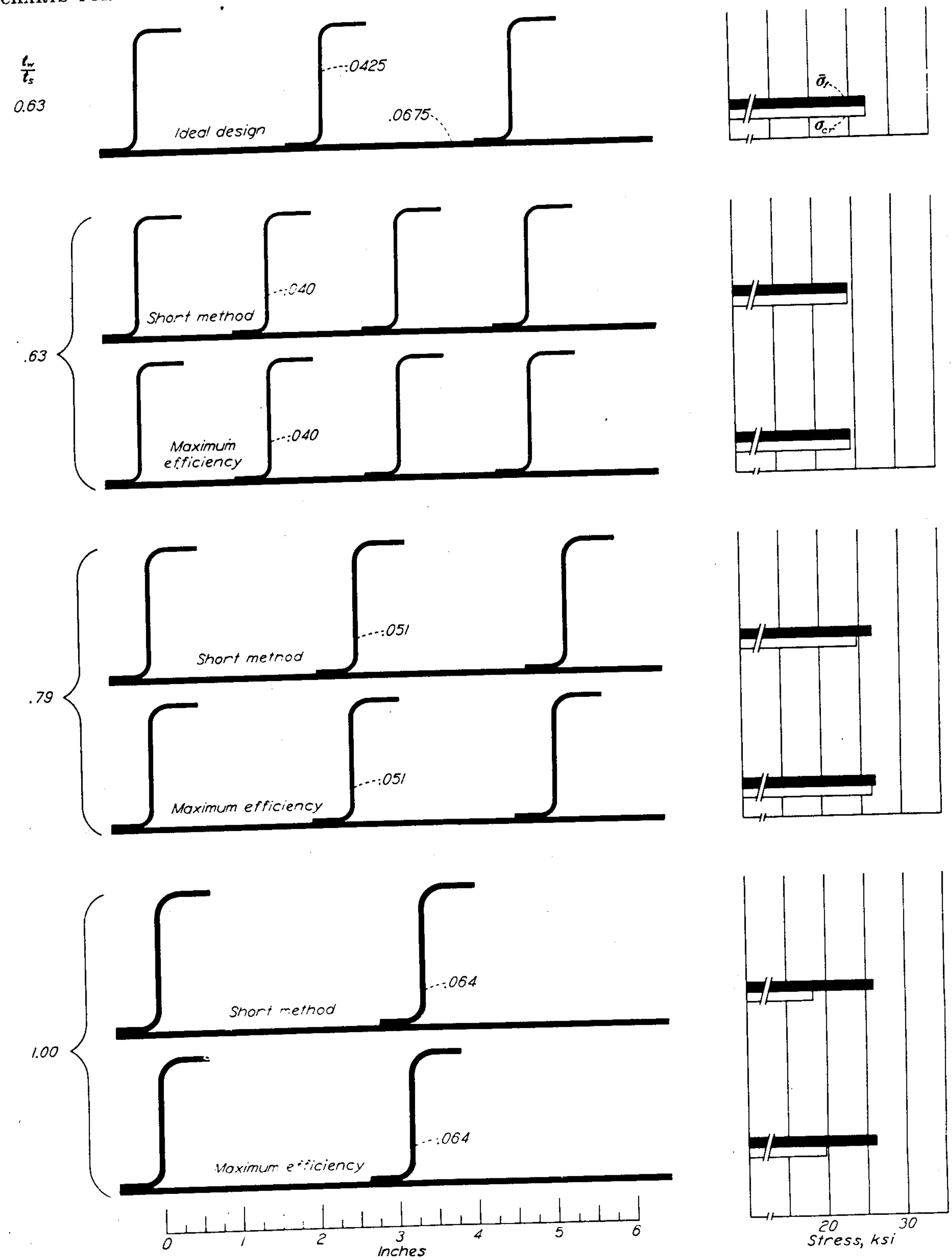

FIGURE 9.—Designs of 24S-T aluminum-alloy panels 30 inches long with P_s=3.0 kips per inch, c=1, and t_s=0.064 inch.

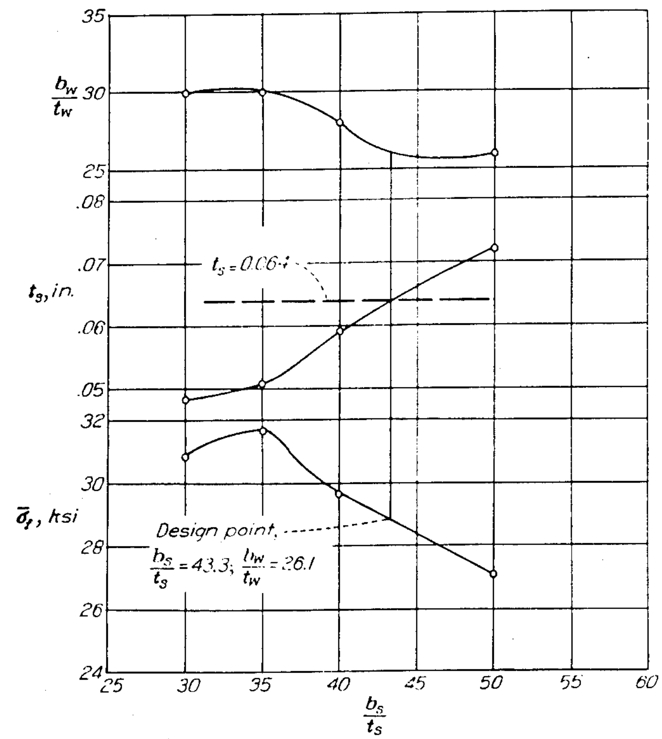

FIGURE 10. Plot for obtaining practical design by short method. P_i=3.0 kips per inch; L=20 inches; c=1; t_S=0.064 inch; $\frac{t_W}{t_S}$=0.79.

Like that for the ideal design, this procedure results, for each length considered, in one design for each value of t_W/t_S. It may not always be possible to find satisfactory designs under the conditions imposed for all values of t_W/t_S. (Note that no designs are given in figs. 8 and 9 for $\frac{t_W}{t_S}$=0.51.) All the designs resulting from the use of the short method utilize standard sheet gages and meet the requirement that t_S=0.064 inch. The choice of design now depends on arriving at a suitable compromise between high stress and wide stiffener spacing. If the prevention of buckling under load is considered important, then the buckling stress must also be taken into account in making a choice.

The designs obtained by carrying out the foregoing procedure for the several values of L and t_W/t_S are shown as the short-method designs in figures 7 to 9 along with bar graphs of the average stress at failure and the buckling stress.

Method of designing for maximum structural efficiency.—The maximum-efficiency method consists of computing the thickness required as b_S/t_S is varied for each value of b_W/t_W and selecting the designs for which the skin gage is equal to that desired. The procedure results in a series of possible designs for each value of t_W/t_S, from which those designs that provide the highest average stress at failure can be selected.

The values and computed quantities for L=20 inches and $\frac{t_W}{t_S}$=0.79 are given in table 6 and are referenced to the steps in the following procedure:

(1) Compute $\frac{P_i}{L/\sqrt{c}}$.

(2) From the curves for a particular value of t_W/t_S (in this example, fig. 4 for $\frac{t_W}{t_S}$=0.79 is used) pick off for each value of b_W/t_W and b_S/t_S the value of $\bar{\sigma}_f$ corresponding to the value of $\frac{P_i}{L/\sqrt{c}}$.

(3) Pick from table 2 the values of A_i/t_S corresponding to the ratios used in step 2.

(4) Compute

$$t_S = \frac{P_i}{\bar{\sigma}_f \frac{A_i}{t_S}}$$

(5) Plot t_S and $\bar{\sigma}_f$ against b_S/t_S for each value of b_W/t_W and t_W/t_S. Plot the particular value of b_W/t_W at the value of b_S/t_S for which t_S equals the specified value and mark the value of stress at that value of b_S/t_S. The plots of this step for the example under consideration are given in figure 11 as the short lines for the several values of b_W/t_W indicated. In order to avoid unnecessary confusion, only short portions of the curves, except the curve for $\frac{b_W}{t_W}$=20, are shown.

(6) After step 5 has been completed for all the values of b_W/t_W, draw curves of stress and of b_W/t_W against b_S/t_S through the points determined in step 5 (heavy curves in fig. 11).

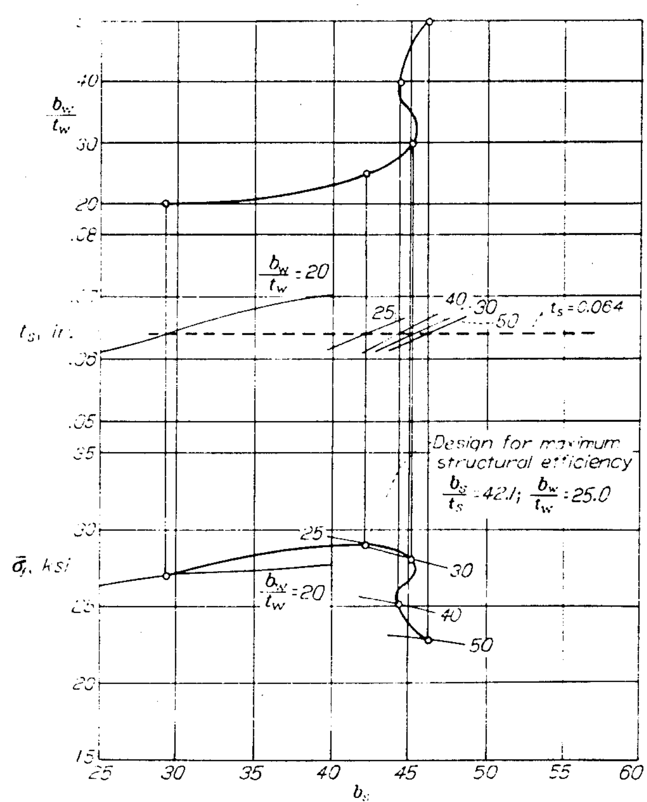

FIGURE 11. Plot for obtaining design for maximum structural efficiency. P_i=3.0 kips per inch; L=20 inches; c=1; t_S=0.064 inch; $\frac{t_W}{t_S}$=0.79.

(7) Each of the curves drawn in step 6 represents a series of designs, all of which have the required value of t_S (in this case, 0.064 in.). The maximum point on the curve of $\overline{\sigma}_f$ indicates the design for maximum structural efficiency for the particular value of t_W/t_S. Note this maximum value of $\overline{\sigma}_f$, the value of b_S/t_S at which it is reached, and the value of b_W/t_W, which can be picked from the curve of b_W/t_W against b_S/t_S.

(8) Check computations by picking from table 2 the value of A_i/t_S corresponding to the ratios selected for maximum structural efficiency in step 7. If all computations and plots are correct,

$$P_i=\overline{\sigma}_f\frac{A_i}{t_S}t_S$$

(9) Compute

$$t_W=\frac{t_W}{t_S}t_S$$

$$b_S=\frac{b_S}{t_S}t_S$$

$$b_W=\frac{b_W}{t_W}t_W$$

(10) Repeat steps 2 to 9 for other values of t_W/t_S.

This procedure results, for each length considered, in one design for each value of t_W/t_S. The choice of a design depends on arriving at a suitable compromise between high stress and wide stiffener spacing, with possible consideration for the buckling stress.

The designs obtained by carrying out the foregoing procedure for the several values of L and t_W/t_S are shown as the maximum-efficiency designs in figures 7 to 9 along with bar graphs of the average stress at failure and the buckling stress.

DISCUSSION

Figures 7 to 9 provide a visual comparison of the designs that result from use of the three methods presented. The short method of design gives in every case an average stress at failure very close to that obtained by designing on the basis of maximum structural efficiency; the buckling stress, however, is in some cases somewhat lower than that for the maximum-efficiency panel.

Whether the design obtained by the short method or the design for maximum efficiency is selected, the best design for $P_i=3.0$ kips per inch, on the basis of stress, is obtained at $L=10$ inches with $\frac{t_W}{t_S}=0.51$, at $L=20$ inches with $\frac{t_W}{t_S}=0.63$, and at $L=30$ inches with $\frac{t_W}{t_S}=0.79$. In figure 6, however, the highest envelope, which gives the lightest design, is that for $\frac{t_W}{t_S}=1.00$. This apparent contradiction results from the fact that in working out the examples a skin thickness of 0.064 inch was specified. In order to reach the curve for $\frac{t_W}{t_S}=1.00$ (fig. 6), a study of table 4 shows that the skin thickness would have to be 0.034 inch at $L=10$ inches, 0.041 inch at 20 inches, and 0.046 inch at 30 inches. Moreover, the stiffener spacings for designs having such small skin thicknesses are very small. (See table 4.) Because of limitations on skin gages and stiffener spacings, therefore, it is frequently not possible to reach the envelope values of stress and hence the lowest possible weight.

Figures 7 to 9 show that the best panel (that with highest $\overline{\sigma}_f$) obtained at each length by the maximum-efficiency method does not buckle until failure or very close to failure. The best panel designed by the short method, although it may not have quite so high an average stress at failure as the maximum-efficiency panel, also does not buckle until very close to failure. This condition has been found to hold true over a wide range of design requirements. It is therefore evident that over a wide range of conditions the maintenance of buckle-free surfaces does not conflict with the achievement of high structural efficiency. The simultaneous achievement of both these ends by use of 24S-T aluminum-alloy panels, however, apparently requires closer stiffener spacings than those now in common use. For example, the maximum-efficiency designs for $P_i=3.0$ kips per inch and $t_S=0.064$ inch have the following spacings for the three lengths:

L (in.)	$\frac{b_S}{t_S}$	b_S (in.)
10	28.0	1.79
20	42.1	2.69
30	40.0	2.56

CONCLUDING REMARKS

Charts are presented for the minimum-weight design of 24S-T aluminum-alloy flat compression panels with longitudinal Z-section stiffeners. From examples based on the use of these charts, it is concluded that, over a wide range of design conditions, the maintenance of buckle-free surfaces on longitudinally stiffened compression panels does not conflict with the achievement of high structural efficiency. The achievement of the maximum possible structural efficiency with 24S-T aluminum-alloy panels, however, requires closer stiffener spacings than those now in common use.

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(8) Check computations by picking from table 2 the value of A_i/t_S corresponding to the ratios selected for maximum structural efficiency in step 7. If all computations and plots are correct,

$$P_i=\overline{\sigma}_f \frac{A_i}{t_S} t_S$$

(9) Compute

$$t_W=\frac{t_W}{t_S} t_S$$

$$b_S=\frac{b_S}{t_S} t_S$$

$$b_W=\frac{b_W}{t_W} t_W$$

(10) Repeat steps 2 to 9 for other values of t_W/t_S.

This procedure results, for each length considered, in one design for each value of t_W/t_S. The choice of a design depends on arriving at a suitable compromise between high stress and wide stiffener spacing, with possible consideration for the buckling stress.

The designs obtained by carrying out the foregoing procedure for the several values of L and t_W/t_S are shown as the maximum-efficiency designs in figures 7 to 9 along with bar graphs of the average stress at failure and the buckling stress.

DISCUSSION

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Whether the design obtained by the short method or the design for maximum efficiency is selected, the best design for $P_i=3.0$ kips per inch, on the basis of stress, is obtained at $L=10$ inches with $\frac{t_W}{t_S}=0.51$, at $L=20$ inches with $\frac{t_W}{t_S}=0.63$, and at $L=30$ inches with $\frac{t_W}{t_S}=0.79$. In figure 6, however, the highest envelope, which gives the lightest design, is that for $\frac{t_W}{t_S}=1.00$. This apparent contradiction results from the fact that in working out the examples a skin thickness of 0.064 inch was specified. In order to reach the curve for $\frac{t_W}{t_S}=1.00$ (fig. 6), a study of table 4 shows that the skin thickness would have to be 0.034 inch at $L=10$ inches, 0.041 inch at 20 inches, and 0.046 inch at 30 inches. Moreover, the stiffener spacings for designs having such small skin thicknesses are very small. (See table 4.) Because of limitations on skin gages and stiffener spacings, therefore, it is frequently not possible to reach the envelope values of stress and hence the lowest possible weight.

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L (in.)	$\frac{b_S}{t_S}$	b_S (in.)
10	28.0	1.79
20	12.1	2.63
30	40.0	2.56

CONCLUDING REMARKS

Charts are presented for the minimum-weight design of 24S–T aluminum-alloy flat compression panels with longitudinal Z-section stiffeners. From examples based on the use of these charts, it is concluded that, over a wide range of design conditions, the maintenance of buckle-free surfaces on longitudinally stiffened compression panels does not conflict with the achievement of high structural efficiency. The achievement of the maximum possible structural efficiency with 24S–T aluminum-alloy panels, however, requires closer stiffener spacings than those now in common use.

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as a guide in fairing the curves, and the curves will be shown to be reasonably accurate for any value of b_F/b_W between 0.3 and 0.5.

Determination of stress for local buckling σ_{cr}.—If the panel did not buckle locally before failure, the theoretical results thus far presented, used in conjunction with values of $\bar{\sigma}_{max}$, would be sufficient to construct a design curve of $\bar{\sigma}_f$ against $\frac{P_i}{L/\sqrt{c}}$ for any panel. A typical curve for panels that do not buckle before failure is shown in figure 13. Unless the width-thickness ratios of the various plate elements of the panel are small or the panel is relatively long, however, there will generally be some local buckling before failure. When this buckling takes place, the cross-sectional moment of inertia of the panel is reduced by the presence of ineffective areas; the original curve of column strength therefore no longer applies and the point at which buckling takes place must be connected with the line for local failure by means of a reduced curve. A typical curve, adjusted for the effects of local buckling, is shown in figure 14.

The foregoing discussion shows that it is necessary to know the stress at which buckling takes place. Data on buckling stresses from reference 2 plus additional data now available are therefore plotted in figure 15 for $\frac{b_F}{b_W}=0.4$. Because the measured value of b/t for the element (skin or stiffener web) that first showed buckling in a test panel was never in exact agreement with the specified nominal value, the observed buckling stresses from reference 2 were corrected for use in figure 15 according to the following formula:

$$(\sigma_{cr})_{corrected}=(\sigma_{cr})_{observed}\frac{\left(\frac{b}{t}\right)^2_{measured}}{\left(\frac{b}{t}\right)^2_{nominal}}$$

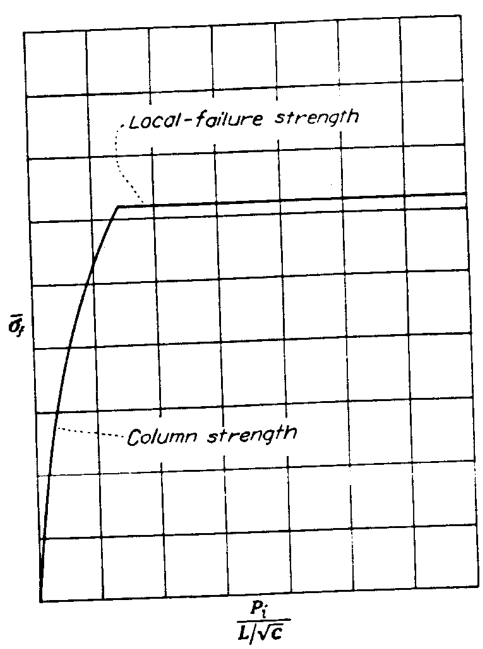


FIGURE 13.—Typical design curve for panels that do not buckle.

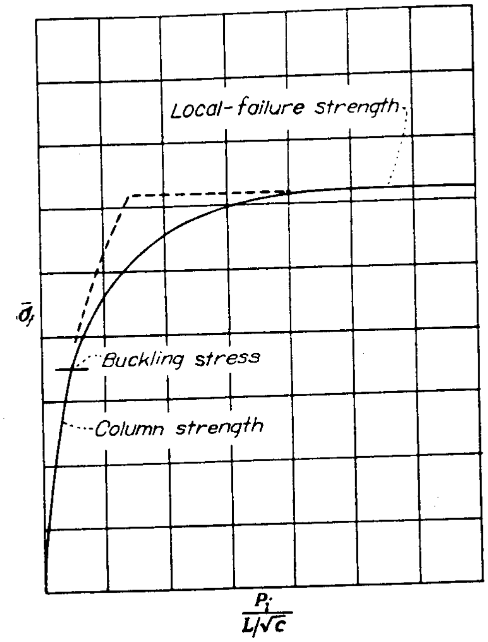


FIGURE 14.—Typical design curve for panels that buckle.

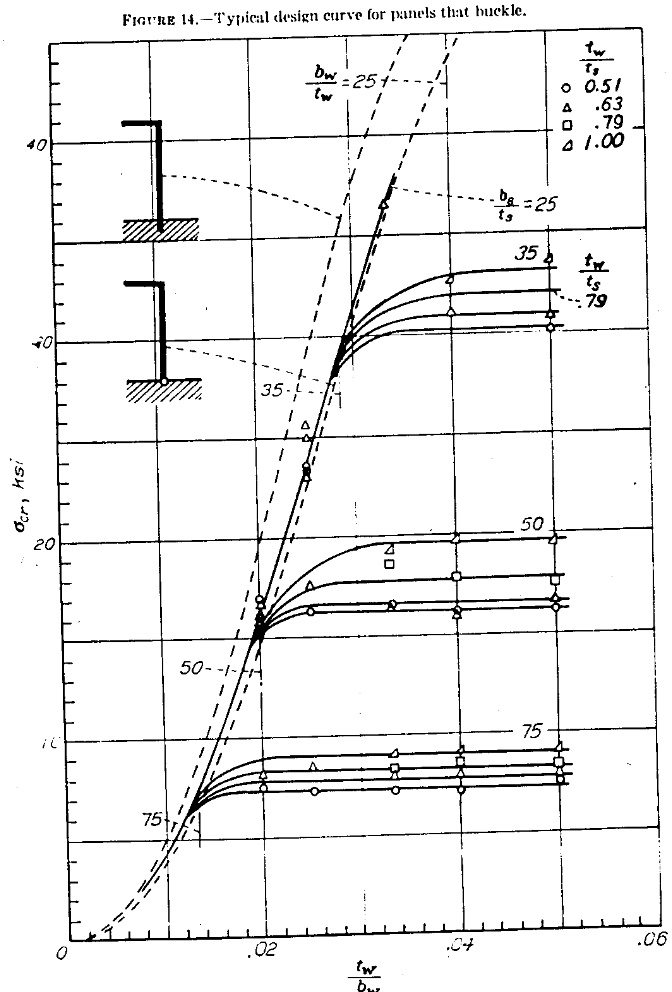


FIGURE 15.—Stress for local buckling of 24S-T aluminum-alloy flat panels with Z-section stiffeners. $\frac{b_F}{b_W}=0.4$.

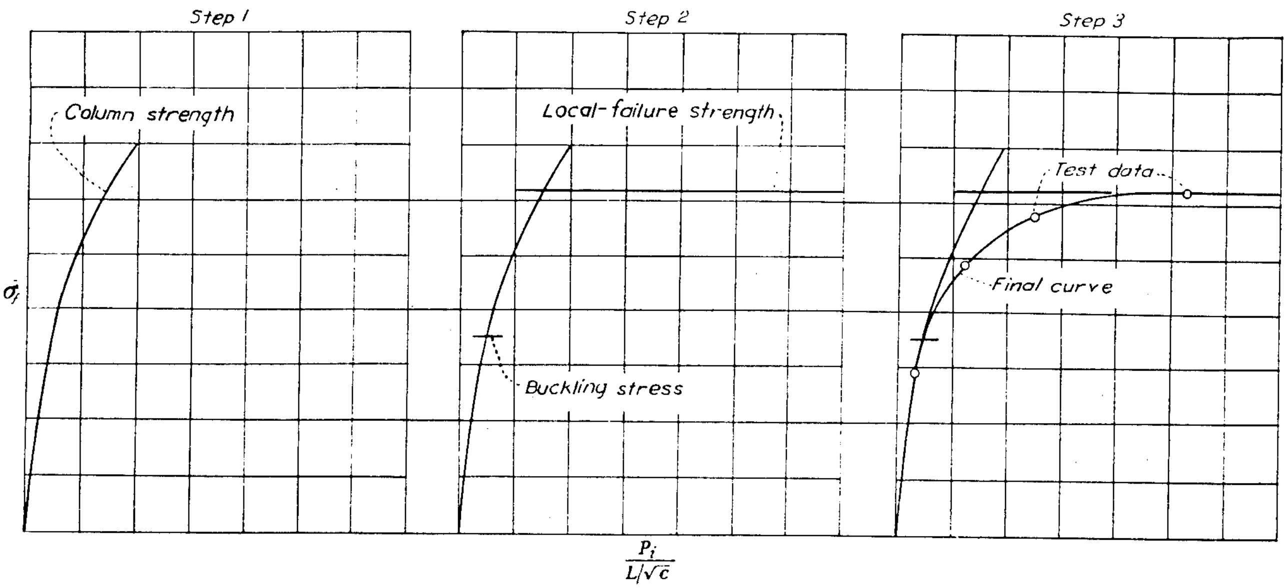


FIGURE 16.—Illustration of procedure used in preparation of design charts.

where the value of b/t is that for the web of the stiffener or for the skin between stiffeners, depending on which of these elements first gave evidence of buckling. This correction formula is based on the fact that, other factors being equal, the critical stress is inversely proportional to the square of the width-thickness ratio. No account is taken herein of the fact that this relationship is not entirely true for stresses beyond the elastic range; it is assumed that neglecting this fact will have no significant effect because the total correction is relatively small.

The method used in fairing curves through the test points in figure 15 is as follows:

For the horizontal portions of the curves on the right-hand side of figure 15, the skin is primarily responsible for the buckling; the ordinates for the curves in this region are determined by drawing average lines through the test points. As the value of t_W/b_W is reduced, however, the responsibility for the buckling shifts to the stiffeners and there is a reduction in σ_{cr}. In the absence of adequate test data for low values of t_W/b_W, certain theoretical considerations are used for determining the values of σ_{cr} in this region.

It is possible to describe certain limiting conditions that determine curves between which the correct curves must lie. As the value of t_W/b_W approaches zero, with all other dimension ratios held constant, the skin tends to become infinitely stiff by comparison with the stiffener and the stiffener approaches a condition of complete fixity at the edge where it is attached to the skin. This condition of complete fixity represents the upper limit of buckling stress. The value of k, the coefficient in the formula for local-buckling stress (reference 4), when applied to the stiffener web may be taken for this condition as the geometric mean of the value of k for the web of a **Z**-section column with $\frac{b_F}{b_W}=0.4$ (about 3.77, see reference 4) and the value of k for a flat plate fixed at both edges (about 6.98, see reference 5). This value of k is $\sqrt{3.77 \times 6.98}$, or 5.13. The upper dashed curve in figure 15 gives σ_{cr} for $k=5.13$. The use of the geometric mean of values of k to obtain the critical stress for a plate with different restraints along the two unloaded edges is discussed and justified for practical use in reference 5.

When $\frac{b_W}{t_W}=\frac{b_S}{t_S}$, it is a reasonable and probably conservative assumption to consider the stiffener hinged at the edge where it is attached to the skin. This hinged condition represents the lower limit of buckling stress. The value of k for the web of the stiffener may be taken for this condition as the geometric mean of 3.77 for the simple **Z**-section and the value for a flat plate hinged at both edges (4.00, see reference 5) or $k=\sqrt{3.77 \times 4.00}=3.88$. The lower dashed curve in figure 15 gives σ_{cr} for $k=3.88$. In the preparation of the two dashed curves, the effect of reduction in the modulus of elasticity for stresses beyond the elastic range was determined from results of tests of 24S-T aluminum-alloy columns of **Z**-, channel, and **H**-section that develop local instability.

The solid curve on the left-hand side of figure 15 is drawn in to give a gradual transition from the lower dashed curve in the region where $\frac{b_W}{t_W}=\frac{b_S}{t_S}$ toward the upper dashed curve as t_W/b_W approaches zero. In the region where $\frac{b_W}{t_W}<\frac{b_S}{t_S}$ the curves are faired into the horizontal lines drawn through the test points. A single curve was considered sufficient for all values of t_W/t_S for the left-hand portion of figure 15, because the few test points that were available in this region indicated that the individual curves would be so close together as to be almost indistinguishable.

The curves of figure 15, like those of figure 12, were cross-plotted to give buckling stresses for the intermediate values of b_S/t_S that appear in figures 2 to 5.

Preparation of final curves.—The procedure used in the preparation of the final curves of figures 2 to 5 is illustrated in figure 16. An outline of this procedure is as follows:

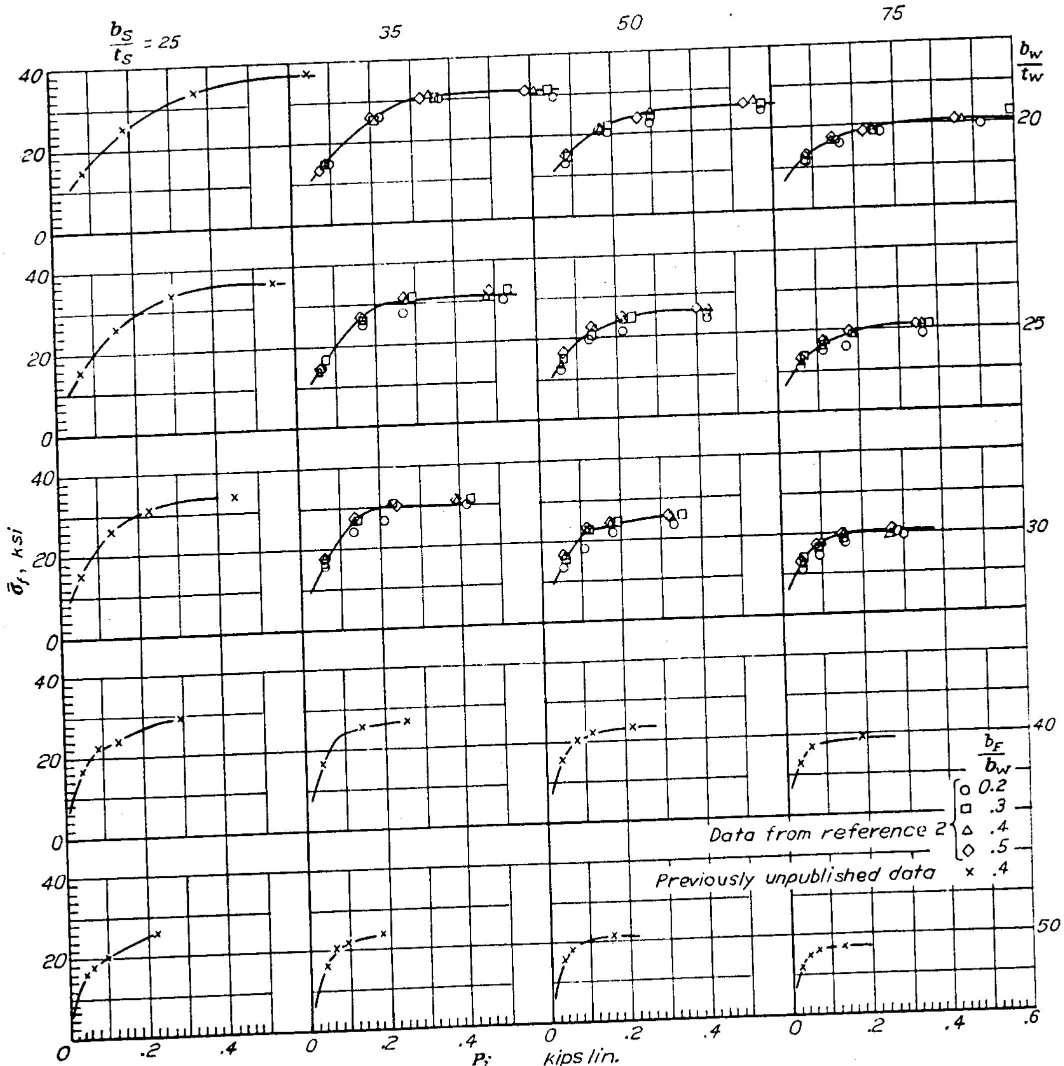


FIGURE 17. Comparison of test data with design curves for 24S-T aluminum-alloy flat panels with Z-section stiffeners. $\frac{t_W}{t_S}=0.51$.

(1) Draw curve for column strength corresponding to the value of ρ/A_i for the panel cross section. For the curves of this report, the column curve for 24S-T aluminum alloy was obtained from equations (5) and (6) and table 1, all of reference 6.

(2) Plot the values of stress for local buckling and for local failure of panel obtained from the cross plots of the curves in figures 12 and 15.

(3) Plot available test data and fair curves between buckling stress and local-failure stress. This fairing was done first for those curves for which test data were available; the remaining curves were then faired in a manner consistent with the curves already established.

In a few cases (low b_S/t_S with high b_W/t_W) the test data indicated that the curves did not follow the smooth transition between column and local failure indicated by figure 16. Instead the curves tended to bend over sharply, in some cases even below the buckling stress given by figure 15, and to follow very nearly a straight line up to the average stress for local failure. No explanation is offered for this phenomenon; the available test data were used as the sole guide for fairing the curves in these cases.

Correlation between design curves and test data.—The test data of reference 2 as well as the additional data made available since the publication of reference 2 are plotted against the parameter $\frac{P_i}{L/\sqrt{c}}$ in figures 17 to 20. Appropriate curves taken from figures 2 to 5 are also drawn in these figures and good agreement between the final design curves and the test data for $\frac{b_F}{b_W}=0.4$ exists throughout the range of the data. In order to make it possible, if desired, to check the correlation on a larger-scale plot, the test data for $\frac{b_F}{b_W}=0.3$, 0.4, and 0.5 are given in table 7 in a form suitable for plotting directly on the design charts (figs. 2 to 5). Table 7 and figures 17 to 20 also make it possible to determine in which regions the design charts are substantiated by test data and in which regions they were obtained by interpolation or extrapolation.

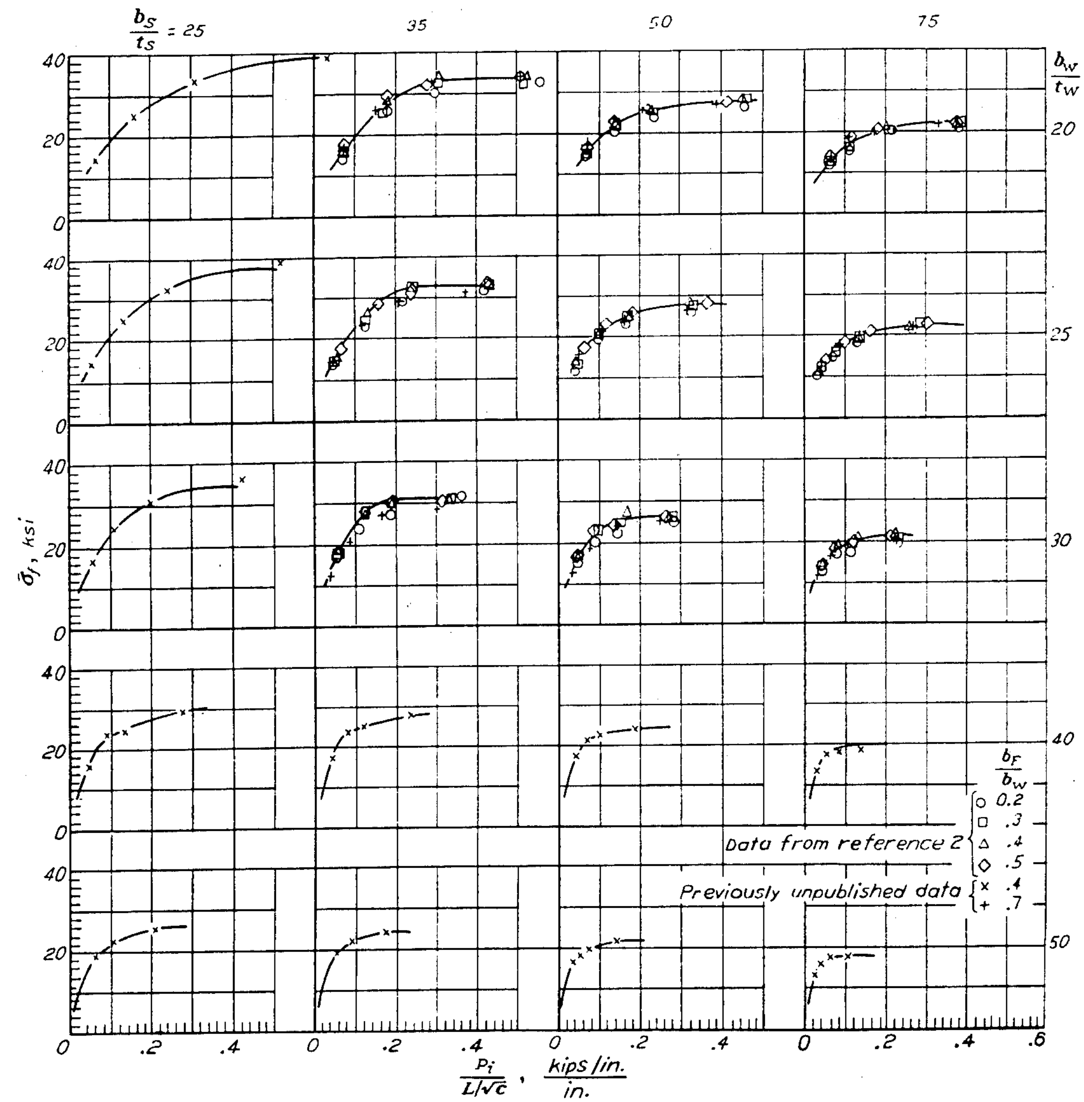


FIGURE 18.—Comparison of test data with design curves for 24S-T aluminum-alloy flat panels with Z-section stiffeners. $\frac{t_W}{t_S}=0.63$.

Figures 17 to 20 indicate that there would be little difference in the curves for $\frac{b_F}{b_W}=0.3$, 0.4, and 0.5 but that the curves for $\frac{b_F}{b_W}=0.2$ and probably 0.7 would be lower than those for $\frac{b_F}{b_W}=0.4$. The most efficient use of material will therefore be realized if a value of b_F/b_W between 0.3 and 0.5 is used. It is for this range that the design charts are intended to be used, although they are based on the specific data for $\frac{b_F}{b_W}=0.4$.

REFERENCES

1. Zahorski, Adam: Effects of Material Distribution on Strength of Panels. Jour. Aero. Sci., vol. 11, no. 3, July 1944, pp. 247–253.
2. Rossman, Carl A., Bartone, Leonard M., and Dobrowski, Charles V.: Compressive Strength of Flat Panels with Z-Section Stiffeners. NACA ARR No. 4B03, 1944.
3. Dow, Norris F., and Hickman, William A.: Preliminary Investigation of the Relation of the Compressive Strength of Sheet-Stiffener Panels to the Diameter of Rivet Used for Attaching Stiffeners to Sheet. NACA RB No. L4I13, 1944.
4. Kroll, W. D., Fisher, Gordon P., and Heimerl, George J.: Charts for Calculation of the Critical Stress for Local Instability of Columns with I-, Z-, Channel, and Rectangular-Tube Section. NACA ARR No. 3K04, 1943.
5. Lundquist, Eugene E., and Stowell, Elbridge Z.: Critical Compressive Stress for Flat Rectangular Plates Supported along All Edges and Elastically Restrained against Rotation along the Unloaded Edges. NACA Rep. No. 733, 1942.
6. Templin, R. L., Sturm, R. G., Hartmann, E. C., and Holt, M.: Column Strength of Various Aluminum Alloys. Tech. Paper No. 1, Aluminum Res. Lab., ALCOA, 1938.

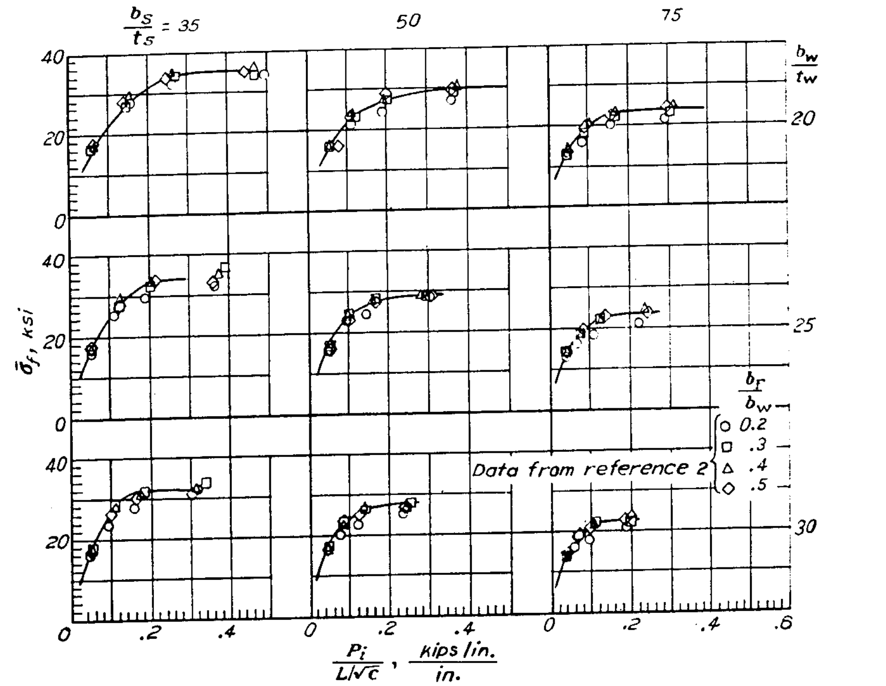


FIGURE 19.—Comparison of test data with design curves for 24S-T aluminum-alloy flat panels with Z-section stiffeners. $\frac{t_w}{t_s}=0.79$.

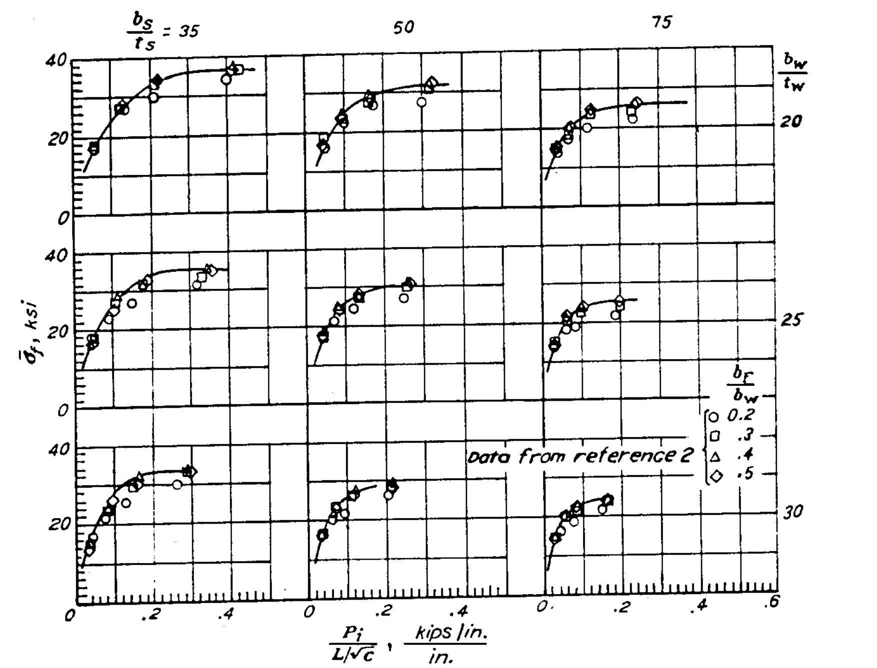


FIGURE 20.—Comparison of test data with design curves for 24S-T aluminum-alloy flat panels with Z-section stiffeners. $\frac{t_w}{t_s}=1.00$.

TABLE I

VALUES OF A_s/t_s FOR FLAT PANELS WITH Z-SECTION STIFFENERS. $\frac{b_F}{b_W}=0.3$.

$$\left[\frac{A_s}{t_s}=1+\frac{\frac{b_W}{t_W}\left(1+\frac{b_F}{b_W}\right)+\frac{b_S}{t_W}-\left(2-\frac{\pi}{2}\right)\left(\frac{r_S}{t_W}+\frac{r_F}{t_W}+1\right)}{b_S/t_S}\left(\frac{t_W}{t_S}\right)^2\right]$$

b_S/t_S \ b_W/t_W	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
											$\frac{t_W}{t_S}=0.51$										
25	1.353	1.367	1.380	1.394	1.407	1.421	1.435	1.448	1.462	1.475	1.489	1.516	1.543	1.570	1.597	1.624	1.651	1.678	1.705	1.732	1.759
26	1.340	1.353	1.366	1.379	1.392	1.405	1.448	1.431	1.444	1.457	1.470	1.496	1.522	1.548	1.574	1.600	1.626	1.652	1.678	1.704	1.730
27	1.327	1.340	1.352	1.365	1.377	1.390	1.402	1.415	1.427	1.440	1.452	1.477	1.502	1.528	1.553	1.578	1.603	1.628	1.653	1.678	1.703
28	1.316	1.328	1.340	1.352	1.364	1.376	1.388	1.400	1.412	1.424	1.436	1.460	1.485	1.509	1.533	1.557	1.581	1.605	1.629	1.654	1.678
29	1.305	1.316	1.328	1.340	1.351	1.363	1.375	1.386	1.398	1.410	1.421	1.445	1.468	1.491	1.514	1.538	1.561	1.584	1.608	1.631	1.654
30	1.294	1.306	1.317	1.328	1.340	1.351	1.362	1.373	1.385	1.396	1.407	1.430	1.452	1.475	1.497	1.520	1.542	1.565	1.587	1.610	1.633
31	1.285	1.296	1.307	1.318	1.329	1.340	1.350	1.361	1.372	1.383	1.394	1.416	1.438	1.459	1.481	1.503	1.525	1.547	1.569	1.590	1.612
32	1.276	1.287	1.297	1.308	1.318	1.329	1.339	1.350	1.361	1.371	1.382	1.403	1.424	1.445	1.466	1.487	1.509	1.730	1.551	1.572	1.593
33	1.268	1.278	1.288	1.298	1.309	1.319	1.329	1.339	1.350	1.360	1.370	1.391	1.411	1.432	1.452	1.473	1.493	1.514	1.534	1.555	1.575
34	1.260	1.270	1.280	1.290	1.300	1.310	1.320	1.329	1.339	1.349	1.359	1.379	1.399	1.419	1.439	1.459	1.479	1.498	1.518	1.538	1.558
35	1.252	1.262	1.272	1.281	1.291	1.301	1.310	1.320	1.330	1.339	1.349	1.368	1.388	1.407	1.426	1.446	1.465	1.484	1.504	1.523	1.542
36	1.245	1.255	1.264	1.274	1.283	1.292	1.302	1.311	1.321	1.330	1.339	1.358	1.377	1.396	1.414	1.433	1.452	1.471	1.490	1.508	1.527
37	1.239	1.248	1.257	1.266	1.275	1.284	1.294	1.303	1.312	1.321	1.330	1.348	1.367	1.385	1.403	1.422	1.440	1.458	1.476	1.495	1.513
38	1.232	1.241	1.250	1.259	1.268	1.277	1.286	1.295	1.304	1.313	1.321	1.339	1.357	1.375	1.393	1.410	1.428	1.446	1.464	1.482	1.499
39	1.227	1.235	1.244	1.253	1.261	1.270	1.279	1.287	1.296	1.305	1.313	1.331	1.348	1.365	1.383	1.400	1.417	1.435	1.452	1.469	1.487
40	1.221	1.229	1.238	1.246	1.255	1.263	1.272	1.280	1.288	1.297	1.305	1.322	1.339	1.356	1.373	1.390	1.407	1.424	1.441	1.458	1.474
42	1.210	1.218	1.226	1.234	1.243	1.251	1.259	1.267	1.275	1.283	1.291	1.307	1.323	1.339	1.355	1.371	1.387	1.404	1.420	1.436	1.452
44	1.201	1.208	1.216	1.224	1.232	1.239	1.247	1.255	1.262	1.270	1.278	1.293	1.308	1.324	1.339	1.354	1.370	1.385	1.401	1.416	1.431
46	1.192	1.199	1.207	1.214	1.221	1.229	1.236	1.244	1.251	1.258	1.266	1.280	1.295	1.310	1.324	1.339	1.354	1.368	1.383	1.398	1.413
48	1.184	1.191	1.198	1.205	1.212	1.219	1.226	1.233	1.240	1.247	1.254	1.269	1.283	1.297	1.311	1.325	1.339	1.353	1.367	1.381	1.395
50	1.177	1.183	1.190	1.197	1.204	1.211	1.217	1.224	1.231	1.238	1.244	1.258	1.271	1.285	1.298	1.312	1.325	1.339	1.353	1.366	1.380
52	1.170	1.176	1.183	1.189	1.196	1.202	1.209	1.215	1.222	1.228	1.235	1.248	1.261	1.274	1.287	1.300	1.313	1.326	1.339	1.352	1.365
54	1.164	1.170	1.176	1.182	1.189	1.195	1.201	1.207	1.214	1.220	1.226	1.239	1.251	1.264	1.276	1.289	1.301	1.314	1.326	1.339	1.351
56	1.158	1.164	1.170	1.176	1.182	1.188	1.194	1.200	1.206	1.212	1.218	1.230	1.242	1.254	1.266	1.279	1.291	1.303	1.315	1.327	1.339
58	1.152	1.158	1.164	1.170	1.176	1.181	1.187	1.193	1.199	1.205	1.211	1.222	1.234	1.246	1.257	1.269	1.281	1.292	1.304	1.316	1.327
60	1.147	1.153	1.159	1.164	1.170	1.175	1.181	1.187	1.192	1.198	1.204	1.215	1.226	1.237	1.249	1.260	1.271	1.282	1.294	1.305	1.316
65	1.136	1.141	1.146	1.152	1.157	1.162	1.167	1.172	1.178	1.183	1.188	1.198	1.209	1.219	1.230	1.240	1.250	1.261	1.271	1.282	1.292
70	1.126	1.131	1.136	1.141	1.146	1.150	1.155	1.160	1.165	1.170	1.175	1.184	1.194	1.203	1.213	1.223	1.232	1.242	1.252	1.261	1.271
75	1.118	1.122	1.127	1.131	1.136	1.140	1.145	1.149	1.154	1.158	1.163	1.172	1.181	1.190	1.199	1.208	1.217	2.226	1.235	1.244	1.253
											$\frac{t_W}{t_S}=0.63$										
25	1.531	1.552	1.573	1.593	1.614	1.635	1.655	1.676	1.696	1.717	1.738	1.779	1.820	1.862	1.903	1.944	1.985	2.027	2.068	2.109	2.151
26	1.511	1.531	1.551	1.570	1.590	1.610	1.630	1.650	1.670	1.690	1.709	1.749	1.789	1.828	1.868	1.908	1.948	1.987	2.027	2.067	2.106
27	1.492	1.511	1.530	1.549	1.568	1.588	1.607	1.626	1.645	1.664	1.683	1.721	1.760	1.798	1.836	1.874	1.912	1.951	1.989	2.027	2.065
28	1.474	1.493	1.511	1.530	1.548	1.567	1.585	1.603	1.622	1.640	1.659	1.696	1.732	1.769	1.806	1.843	1.880	1.917	1.954	1.990	2.027
29	1.458	1.476	1.494	1.511	1.529	1.547	1.565	1.583	1.600	1.618	1.636	1.672	1.707	1.743	1.778	1.814	1.849	1.885	1.921	1.956	1.992
30	1.443	1.460	1.477	1.494	1.512	1.529	1.546	1.563	1.580	1.598	1.615	1.649	1.684	1.718	1.752	1.787	1.821	1.856	1.890	1.924	1.959
31	1.428	1.445	1.462	1.478	1.495	1.512	1.528	1.545	1.562	1.578	1.595	1.628	1.662	1.695	1.728	1.761	1.795	1.828	1.861	1.895	1.928
32	1.415	1.431	1.447	1.463	1.480	1.496	1.512	1.528	1.544	1.560	1.576	1.609	1.641	1.673	1.705	1.738	1.770	1.802	1.834	1.867	1.899
33	1.403	1.418	1.434	1.449	1.465	1.481	1.496	1.512	1.528	1.543	1.559	1.590	1.621	1.653	1.684	1.715	1.747	1.778	1.809	1.840	1.872
34	1.391	1.406	1.421	1.436	1.451	1.467	1.482	1.497	1.512	1.527	1.542	1.573	1.603	1.634	1.664	1.694	1.725	1.755	1.785	1.816	1.846
35	1.380	1.394	1.409	1.424	1.438	1.453	1.468	1.483	1.497	1.512	1.527	1.556	1.586	1.615	1.645	1.674	1.704	1.733	1.763	1.792	1.822
36	1.369	1.383	1.398	1.412	1.426	1.441	1.455	1.469	1.484	1.498	1.512	1.541	1.570	1.598	1.627	1.656	1.684	1.713	1.742	1.770	1.799
37	1.359	1.373	1.387	1.401	1.415	1.429	1.443	1.457	1.471	1.485	1.498	1.526	1.554	1.582	1.610	1.638	1.666	1.694	1.722	1.749	1.777
38	1.350	1.363	1.377	1.390	1.404	1.417	1.431	1.445	1.458	1.472	1.485	1.513	1.540	1.567	1.594	1.621	1.648	1.675	1.703	1.730	1.757
39	1.341	1.354	1.367	1.380	1.394	1.407	1.420	1.433	1.446	1.460	1.473	1.499	1.526	1.552	1.579	1.605	1.632	1.658	1.685	1.711	1.738
40	1.332	1.345	1.358	1.371	1.384	1.397	1.409	1.422	1.435	1.448	1.461	1.487	1.513	1.538	1.564	1.590	1.616	1.642	1.667	1.693	1.719
42	1.316	1.329	1.341	1.353	1.365	1.378	1.390	1.402	1.415	1.427	1.439	1.464	1.488	1.513	1.537	1.562	1.587	1.611	1.636	1.660	1.685
44	1.302	1.314	1.325	1.337	1.349	1.361	1.372	1.384	1.396	1.407	1.419	1.443	1.466	1.490	1.513	1.536	1.560	1.583	1.607	1.630	1.654
46	1.289	1.300	1.311	1.322	1.334	1.345	1.356	1.367	1.379	1.390	1.401	1.423	1.446	1.468	1.491	1.513	1.536	1.558	1.580	1.603	1.625
48	1.277	1.287	1.298	1.309	1.320	1.330	1.341	1.352	1.363	1.373	1.384	1.406	1.427	1.449	1.470	1.492	1.513	1.535	1.556	1.578	1.599
50	1.266	1.276	1.286	1.297	1.307	1.317	1.328	1.338	1.348	1.359	1.369	1.390	1.410	1.431	1.451	1.472	1.493	1.513	1.534	1.555	1.575
52	1.255	1.265	1.275	1.285	1.295	1.305	1.315	1.325	1.335	1.345	1.355	1.375	1.394	1.414	1.434	1.454	1.474	1.494	1.513	1.533	1.553
54	1.246	1.256	1.265	1.275	1.284	1.294	1.303	1.313	1.322	1.332	1.342	1.361	1.380	1.399	1.418	1.437	1.456	1.475	1.494	1.514	1.533
56	1.237	1.246	1.256	1.265	1.274	1.283	1.292	1.302	1.311	1.320	1.329	1.348	1.366	1.385	1.403	1.421	1.440	1.458	1.477	1.495	1.514
58	1.229	1.238	1.247	1.256	1.265	1.273	1.282	1.291	1.300	1.309	1.318	1.336	1.354	1.371	1.389	1.407	1.425	1.443	1.460	1.478	1.496
60	1.221	1.230	1.239	1.247	1.256	1.264	1.273	1.282	1.290	1.299	1.307	1.325	1.342	1.359	1.376	1.393	1.411	1.428	1.445	1.462	1.479
65	1.204	1.212	1.220	1.228	1.236	1.244	1.252	1.260	1.268	1.276	1.284	1.300	1.316	1.331	1.347	1.363	1.379	1.395	1.411	1.427	1.443
70	1.190	1.197	1.205	1.212	1.219	1.227	1.234	1.241	1.249	1.256	1.263	1.278	1.293	1.308	1.322	1.337	1.352	1.367	1.381	1.396	1.411
75	1.177	1.184	1.191	1.198	1.205	1.212	1.218	1.225	1.232	1.239	1.246	1.260	1.273	1.287	1.301	1.315	1.328	1.342	1.356	1.370	1.384

TABLE 1—Concluded

VALUES OF A_r/t_S FOR FLAT PANELS WITH Z-SECTION STIFFENERS, $\frac{b_F}{b_W}=0.3$—Concluded.

b_S/t_S \ b_W/t_W	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
$\frac{t_W}{t_S}=0.79$																					
25	1.808	1.840	1.873	1.905	1.938	1.970	2.003	2.035	2.068	2.100	2.133	2.197	2.262	2.327	2.392	2.457	2.522	2.587	2.652	2.717	2.782
26	1.777	1.808	1.839	1.871	1.902	1.933	1.964	1.995	2.027	2.058	2.089	2.151	2.214	2.276	2.339	2.401	2.463	2.526	2.588	2.651	2.713
27	1.748	1.778	1.808	1.838	1.868	1.898	1.928	1.958	1.989	2.019	2.049	2.109	2.169	2.229	2.289	2.349	2.409	2.469	2.529	2.590	2.650
28	1.721	1.750	1.779	1.808	1.837	1.866	1.895	1.924	1.953	1.982	2.011	2.069	2.127	2.185	2.243	2.301	2.359	2.417	2.475	2.533	2.590
29	1.697	1.725	1.752	1.780	1.808	1.836	1.864	1.892	1.920	1.948	1.976	2.032	2.088	2.144	2.200	2.256	2.312	2.368	2.424	2.480	2.536
30	1.673	1.700	1.727	1.754	1.781	1.809	1.836	1.863	1.890	1.917	1.944	1.998	2.052	2.106	2.160	2.214	2.268	2.322	2.376	2.431	2.485
31	1.652	1.678	1.704	1.730	1.756	1.782	1.809	1.835	1.861	1.887	1.913	1.966	2.018	2.070	2.123	2.175	2.227	2.280	2.332	2.384	2.437
32	1.631	1.657	1.682	1.707	1.733	1.758	1.783	1.809	1.834	1.859	1.885	1.935	1.986	2.037	2.088	2.138	2.189	2.240	2.290	2.341	2.392
33	1.612	1.637	1.661	1.686	1.710	1.735	1.760	1.784	1.809	1.833	1.858	1.907	1.956	2.006	2.055	2.104	2.153	2.202	2.251	2.301	2.350
34	1.594	1.618	1.642	1.666	1.690	1.713	1.737	1.761	1.785	1.809	1.833	1.880	1.928	1.976	2.024	2.071	2.119	2.167	2.215	2.262	2.310
35	1.577	1.600	1.623	1.647	1.670	1.693	1.716	1.739	1.763	1.786	1.809	1.855	1.902	1.948	1.994	2.041	2.087	2.133	2.180	2.226	2.273
36	1.561	1.584	1.606	1.629	1.651	1.674	1.696	1.719	1.741	1.764	1.786	1.832	1.877	1.922	1.967	2.012	2.057	2.102	2.147	2.192	1.237
37	1.546	1.568	1.590	1.612	1.634	1.656	1.677	1.699	1.721	1.743	1.765	1.809	1.853	1.897	1.941	1.984	2.028	2.072	2.116	2.160	2.204
38	1.532	1.553	1.574	1.596	1.617	1.638	1.660	1.681	1.702	1.724	1.745	1.788	1.830	1.873	1.916	1.959	2.001	2.044	2.087	2.129	2.172
39	1.518	1.539	1.560	1.580	1.601	1.622	1.643	1.664	1.684	1.705	1.726	1.768	1.809	1.851	1.892	1.934	1.976	2.017	2.059	2.100	2.142
40	1.505	1.525	1.546	1.566	1.586	1.606	1.627	1.647	1.667	1.688	1.708	1.748	1.789	1.830	1.870	1.911	1.951	1.992	2.032	2.073	2.114
42	1.481	1.500	1.520	1.539	1.558	1.578	1.597	1.616	1.635	1.655	1.674	1.713	1.751	1.790	1.829	1.967	1.906	1.945	1.983	2.022	2.060
44	1.459	1.478	1.496	1.514	1.533	1.551	1.570	1.588	1.607	1.625	1.643	1.680	1.717	1.754	1.791	1.828	1.865	1.902	1.938	1.975	2.012
46	1.439	1.457	1.474	1.492	1.510	1.527	1.545	1.563	1.580	1.598	1.615	1.651	1.686	1.721	1.757	1.792	1.827	1.862	1.898	1.933	1.968
48	1.421	1.438	1.455	1.472	1.488	1.505	1.522	1.539	1.556	1.573	1.590	1.624	1.657	1.691	1.725	1.759	1.793	1.826	1.860	1.894	1.928
50	1.404	1.420	1.436	1.453	1.469	1.485	1.501	1.518	1.534	1.550	1.566	1.599	1.631	1.664	1.696	1.729	1.761	1.793	1.826	1.858	1.891
52	1.388	1.404	1.420	1.435	1.451	1.466	1.482	1.498	1.513	1.529	1.544	1.576	1.607	1.638	1.669	1.700	1.732	1.763	1.794	1.825	1.857
54	1.374	1.389	1.404	1.419	1.434	1.449	1.464	1.479	1.494	1.509	1.524	1.554	1.584	1.614	1.645	1.675	1.705	1.735	1.765	1.795	1.825
56	1.361	1.375	1.390	1.404	1.419	1.433	1.448	1.462	1.477	1.491	1.506	1.535	1.564	1.593	1.621	1.650	1.679	1.708	1.737	1.766	1.795
58	1.348	1.362	1.376	1.390	1.404	1.418	1.432	1.446	1.460	1.474	1.488	1.516	1.544	1.572	1.600	1.628	1.656	1.684	1.712	1.740	1.768
60	1.337	1.350	1.364	1.377	1.391	1.404	1.418	1.431	1.445	1.458	1.472	1.499	1.526	1.553	1.580	1.607	1.634	1.661	1.688	1.715	1.742
65	1.311	1.323	1.336	1.348	1.361	1.373	1.386	1.398	1.411	1.423	1.436	1.461	1.486	1.510	1.535	1.560	1.585	1.610	1.635	1.660	1.685
70	1.289	1.300	1.312	1.323	1.335	1.347	1.358	1.370	1.381	1.393	1.404	1.428	1.451	1.474	1.497	1.520	1.544	1.567	1.590	1.613	1.636
75	1.269	1.280	1.291	1.302	1.313	1.323	1.334	1.345	1.356	1.367	1.377	1.399	1.421	1.442	1.464	1.486	1.507	1.529	1.551	1.572	1.594
$\frac{t_W}{t_S}=1.00$																					
25	2.247	2.299	2.351	2.403	2.455	2.506	2.559	2.611	2.663	2.715	2.767	2.871	2.975	3.079	3.183	3.287	3.291	3.495	3.599	3.703	3.807
26	2.199	2.249	2.299	2.349	2.399	2.449	2.499	2.549	2.599	2.649	2.699	2.799	2.899	2.999	3.099	3.199	3.299	3.399	3.499	3.599	3.699
27	2.154	2.202	2.251	2.299	2.347	2.395	2.443	2.491	2.540	2.588	2.636	2.732	2.828	2.925	3.021	3.117	3.214	3.310	3.406	3.502	3.599
28	2.113	2.160	2.206	2.252	2.299	2.345	2.392	2.438	2.485	2.531	2.577	2.670	2.763	2.856	2.949	3.042	3.135	3.227	3.320	3.413	3.506
29	2.075	2.120	2.164	2.209	2.254	2.299	2.344	2.389	2.433	2.478	2.523	2.613	2.702	2.792	2.882	2.971	3.061	3.151	3.240	3.330	3.420
30	2.039	2.082	2.126	2.169	2.212	2.256	2.299	2.342	2.386	2.429	2.472	2.559	2.646	2.732	2.819	2.906	2.992	3.079	3.166	3.252	3.339
31	2.005	2.047	2.089	2.131	2.173	2.215	2.257	2.299	2.341	2.383	2.425	2.509	2.592	2.676	2.760	2.844	2.928	3.012	3.096	3.180	3.263
32	1.974	2.015	2.055	2.096	2.136	2.177	2.218	2.258	2.299	2.340	2.380	2.461	2.543	2.624	2.705	2.786	2.868	2.949	3.030	3.111	3.193
33	1.944	1.984	2.023	2.063	2.102	2.141	2.181	2.220	2.260	2.299	2.338	2.417	2.496	2.575	2.654	2.732	2.811	2.890	2.969	3.048	3.126
34	1.917	1.955	1.993	2.031	2.070	2.108	2.146	2.184	2.223	2.261	2.299	2.376	2.452	2.528	2.605	2.681	2.758	2.834	2.911	2.987	3.064
35	1.890	1.928	1.965	2.002	2.039	2.076	2.113	2.150	2.188	2.225	2.262	2.336	2.410	2.485	2.559	2.633	2.708	2.782	2.856	2.930	3.005
36	1.866	1.902	1.938	1.974	2.010	2.046	2.082	2.119	2.155	2.191	2.227	2.299	2.371	2.444	2.516	2.588	2.660	2.732	2.805	2.877	2.949
37	1.842	1.877	1.913	1.948	1.983	2.018	2.053	2.088	2.123	2.159	2.194	2.264	2.334	2.405	2.475	2.545	2.615	2.686	2.756	2.826	2.896
38	1.820	1.854	1.889	1.923	1.957	1.991	2.025	2.060	2.094	2.128	2.162	2.231	2.299	2.368	2.436	2.504	2.573	2.641	2.710	2.778	2.847
39	1.799	1.832	1.866	1.899	1.932	1.966	1.999	2.033	2.066	2.099	2.133	2.199	2.266	2.333	2.399	2.466	2.533	2.599	2.666	2.733	2.799
40	1.779	1.812	1.844	1.877	1.909	1.942	1.974	2.007	2.039	2.072	2.104	2.169	2.234	2.299	2.364	2.429	2.494	2.559	2.624	2.689	2.754
42	1.742	1.773	1.804	1.835	1.866	1.897	1.928	1.959	1.990	2.021	2.052	2.114	2.175	2.237	2.299	2.361	2.423	2.485	2.547	2.609	2.671
44	1.708	1.738	1.767	1.797	1.826	1.856	1.886	1.915	1.945	1.974	2.004	2.063	2.122	2.181	2.240	2.299	2.358	2.417	2.477	2.536	2.595
46	1.678	1.706	1.734	1.762	1.791	1.819	1.847	1.875	1.904	1.932	1.960	2.017	2.073	2.130	2.186	2.243	2.299	2.356	2.412	2.469	2.525
48	1.649	1.676	1.703	1.731	1.758	1.785	1.812	1.839	1.866	1.893	1.920	1.974	2.028	2.083	2.137	2.191	2.215	2.299	2.353	2.408	2.462
50	1.623	1.649	1.675	1.701	1.727	1.753	1.779	1.805	1.831	1.857	1.883	1.935	1.987	2.039	2.091	2.143	2.195	2.247	2.299	2.351	2.403
52	1.599	1.624	1.649	1.674	1.699	1.724	1.749	1.774	1.799	1.824	1.849	1.899	1.949	1.999	2.049	2.099	2.149	2.199	2.219	2.299	2.349
54	1.577	1.601	1.625	1.649	1.673	1.698	1.722	1.746	1.770	1.794	1.818	1.866	1.914	1.962	2.011	2.059	2.107	2.155	2.203	2.251	2.299
56	1.557	1.580	1.603	1.626	1.649	1.673	1.696	1.719	1.742	1.765	1.789	1.835	1.882	1.928	1.974	2.021	2.067	2.114	2.160	2.207	2.253
58	1.537	1.560	1.582	1.605	1.627	1.649	1.672	1.694	1.717	1.739	1.761	1.806	1.851	1.896	1.941	1.986	2.030	2.075	2.120	2.165	2.210
60	1.519	1.541	1.563	1.584	1.606	1.628	1.649	1.671	1.693	1.714	1.736	1.779	1.823	1.866	1.909	1.953	1.996	2.040	2.083	2.126	2.170
65	1.479	1.499	1.519	1.539	1.559	1.579	1.599	1.619	1.639	1.659	1.679	1.719	1.760	1.800	1.840	1.880	1.920	1.960	2.000	2.040	2.080
70	1.445	1.464	1.482	1.501	1.520	1.538	1.557	1.575	1.594	1.612	1.631	1.668	1.705	1.742	1.780	1.817	1.854	1.891	1.928	1.965	2.002
75	1.416	1.433	1.450	1.468	1.485	1.502	1.520	1.537	1.554	1.572	1.589	1.624	1.658	1.693	1.728	1.762	1.797	1.832	1.866	1.901	1.936

TABLE 2

VALUES OF A_t/t_S FOR FLAT PANELS WITH Z-SECTION STIFFENERS. $\frac{b_F}{b_W}=0.4$.

$$\left[\frac{A_t}{t_S}=1+\frac{\frac{b_W}{t_W}\left(1+\frac{b_F}{b_W}\right)+\frac{b_A}{t_W}-\left(2-\frac{\pi}{2}\right)\left(\frac{r_A}{t_W}+\frac{r_F}{t_W}+1\right)}{b_S/t_S}\left(\frac{t_W}{t_S}\right)^2\right]$$

b_S/t_S \ b_W/t_W	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
$\frac{t_W}{t_S}=0.51$																					
25	1.374	1.389	1.403	1.418	1.432	1.447	1.462	1.476	1.491	1.505	1.520	1.549	1.578	1.607	1.636	1.665	1.695	1.724	1.753	1.782	1.811
26	1.360	1.374	1.388	1.402	1.416	1.430	1.444	1.458	1.472	1.486	1.500	1.528	1.556	1.584	1.612	1.640	1.668	1.696	1.724	1.752	1.780
27	1.346	1.360	1.373	1.387	1.400	1.414	1.427	1.441	1.454	1.468	1.481	1.508	1.535	1.562	1.589	1.616	1.643	1.670	1.697	1.724	1.751
28	1.334	1.347	1.360	1.373	1.386	1.399	1.412	1.425	1.438	1.451	1.464	1.490	1.516	1.542	1.568	1.594	1.620	1.646	1.672	1.698	1.724
29	1.323	1.335	1.348	1.360	1.373	1.385	1.398	1.410	1.423	1.436	1.448	1.473	1.498	1.523	1.549	1.574	1.599	1.624	1.649	1.674	1.699
30	1.312	1.324	1.336	1.348	1.360	1.373	1.385	1.397	1.409	1.421	1.433	1.457	1.482	1.506	1.530	1.555	1.579	1.603	1.627	1.652	1.676
31	1.302	1.313	1.325	1.337	1.349	1.360	1.372	1.384	1.396	1.407	1.419	1.443	1.466	1.490	1.513	1.537	1.560	1.584	1.607	1.631	1.654
32	1.292	1.304	1.315	1.326	1.338	1.349	1.361	1.372	1.383	1.395	1.406	1.429	1.452	1.474	1.497	1.520	1.543	1.565	1.588	1.611	1.634
33	1.283	1.294	1.306	1.317	1.328	1.339	1.350	1.361	1.372	1.383	1.394	1.416	1.438	1.460	1.482	1.504	1.526	1.548	1.570	1.592	1.614
34	1.275	1.286	1.297	1.307	1.318	1.329	1.339	1.350	1.361	1.372	1.382	1.404	1.425	1.446	1.468	1.489	1.511	1.532	1.554	1.575	1.596
35	1.267	1.278	1.288	1.298	1.309	1.319	1.330	1.340	1.350	1.361	1.371	1.392	1.413	1.434	1.455	1.475	1.496	1.517	1.538	1.559	1.579
36	1.260	1.270	1.280	1.290	1.300	1.310	1.321	1.331	1.341	1.351	1.361	1.381	1.401	1.422	1.442	1.462	1.482	1.503	1.523	1.543	1.563
37	1.253	1.263	1.272	1.282	1.292	1.302	1.312	1.322	1.332	1.341	1.351	1.371	1.391	1.410	1.430	1.450	1.469	1.489	1.509	1.528	1.548
38	1.246	1.256	1.265	1.275	1.285	1.294	1.304	1.313	1.323	1.332	1.342	1.361	1.380	1.399	1.419	1.438	1.457	1.476	1.495	1.514	1.534
39	1.240	1.249	1.259	1.268	1.277	1.287	1.296	1.305	1.315	1.324	1.333	1.352	1.371	1.389	1.408	1.427	1.445	1.464	1.483	1.501	1.520
40	1.234	1.243	1.252	1.261	1.270	1.279	1.288	1.298	1.307	1.316	1.325	1.343	1.361	1.380	1.398	1.416	1.434	1.452	1.471	1.489	1.507
42	1.223	1.231	1.240	1.249	1.257	1.266	1.275	1.283	1.292	1.301	1.309	1.327	1.344	1.361	1.379	1.396	1.413	1.431	1.448	1.465	1.483
44	1.213	1.221	1.229	1.237	1.246	1.254	1.262	1.271	1.279	1.287	1.295	1.312	1.328	1.345	1.362	1.378	1.395	1.411	1.428	1.444	1.461
46	1.203	1.211	1.219	1.227	1.235	1.243	1.251	1.259	1.267	1.275	1.283	1.298	1.314	1.330	1.346	1.362	1.377	1.393	1.409	1.425	1.441
48	1.195	1.202	1.210	1.218	1.225	1.233	1.240	1.248	1.256	1.263	1.271	1.286	1.301	1.316	1.331	1.347	1.362	1.377	1.392	1.407	1.422
50	1.187	1.194	1.202	1.209	1.216	1.224	1.231	1.238	1.245	1.253	1.260	1.274	1.289	1.304	1.318	1.333	1.347	1.362	1.376	1.391	1.406
52	1.180	1.187	1.194	1.201	1.208	1.215	1.222	1.229	1.236	1.243	1.250	1.264	1.278	1.292	1.306	1.320	1.334	1.348	1.362	1.376	1.390
54	1.173	1.180	1.187	1.193	1.200	1.207	1.214	1.220	1.227	1.234	1.241	1.254	1.268	1.281	1.295	1.308	1.322	1.335	1.349	1.362	1.376
56	1.167	1.174	1.180	1.187	1.193	1.200	1.206	1.213	1.219	1.226	1.232	1.245	1.258	1.271	1.284	1.297	1.310	1.323	1.336	1.349	1.362
58	1.161	1.168	1.174	1.180	1.186	1.193	1.199	1.205	1.212	1.218	1.224	1.237	1.249	1.262	1.274	1.287	1.299	1.312	1.324	1.337	1.350
60	1.156	1.162	1.168	1.174	1.180	1.186	1.192	1.198	1.204	1.211	1.217	1.229	1.241	1.253	1.265	1.277	1.289	1.302	1.314	1.326	1.338
65	1.144	1.150	1.155	1.161	1.166	1.172	1.178	1.183	1.189	1.194	1.200	1.211	1.222	1.234	1.245	1.256	1.267	1.278	1.290	1.301	1.312
70	1.134	1.139	1.144	1.149	1.154	1.160	1.165	1.170	1.175	1.180	1.186	1.196	1.206	1.217	1.227	1.238	1.248	1.258	1.269	1.279	1.290
75	1.125	1.130	1.134	1.139	1.144	1.149	1.154	1.159	1.164	1.168	1.173	1.183	1.193	1.202	1.212	1.222	1.232	1.241	1.251	1.261	1.270
$\frac{t_W}{t_S}=0.53$																					
25	1.563	1.585	1.608	1.630	1.652	1.674	1.696	1.719	1.741	1.763	1.785	1.830	1.874	1.919	1.963	2.008	2.052	2.097	2.141	2.186	2.230
26	1.541	1.563	1.584	1.606	1.627	1.648	1.670	1.691	1.712	1.734	1.755	1.798	1.841	1.883	1.926	1.969	2.012	2.054	2.097	2.140	2.183
27	1.521	1.542	1.563	1.583	1.604	1.624	1.645	1.665	1.686	1.707	1.727	1.768	1.810	1.851	1.892	1.933	1.974	2.015	2.057	2.098	2.139
28	1.503	1.523	1.542	1.562	1.582	1.602	1.622	1.642	1.662	1.681	1.701	1.741	1.781	1.820	1.860	1.900	1.939	1.979	2.019	2.059	2.098
29	1.485	1.505	1.524	1.543	1.562	1.581	1.600	1.620	1.639	1.658	1.677	1.715	1.754	1.792	1.830	1.869	1.907	1.945	1.984	2.022	2.060
30	1.469	1.488	1.506	1.525	1.543	1.562	1.580	1.599	1.617	1.636	1.654	1.692	1.729	1.766	1.803	1.840	1.877	1.914	1.951	1.988	2.025
31	1.454	1.472	1.490	1.508	1.526	1.544	1.562	1.580	1.598	1.615	1.633	1.669	1.705	1.741	1.777	1.813	1.848	1.884	1.920	1.956	1.992
32	1.440	1.457	1.475	1.492	1.509	1.527	1.544	1.561	1.579	1.596	1.614	1.648	1.683	1.718	1.753	1.787	1.822	1.857	1.891	1.926	1.961
33	1.427	1.443	1.460	1.477	1.494	1.511	1.528	1.544	1.561	1.578	1.595	1.629	1.662	1.696	1.730	1.763	1.797	1.831	1.864	1.898	1.932
34	1.414	1.430	1.447	1.463	1.479	1.496	1.512	1.528	1.545	1.561	1.577	1.610	1.643	1.676	1.708	1.741	1.774	1.806	1.839	1.872	1.904
35	1.402	1.418	1.434	1.450	1.466	1.482	1.497	1.513	1.530	1.545	1.561	1.593	1.624	1.656	1.688	1.720	1.752	1.783	1.815	1.847	1.879
36	1.391	1.406	1.422	1.437	1.453	1.468	1.484	1.499	1.515	1.530	1.545	1.576	1.607	1.638	1.669	1.700	1.731	1.762	1.792	1.823	1.854
37	1.380	1.395	1.411	1.426	1.441	1.456	1.471	1.486	1.501	1.516	1.531	1.561	1.591	1.621	1.651	1.681	1.711	1.741	1.771	1.801	1.831
38	1.370	1.385	1.400	1.414	1.429	1.444	1.458	1.473	1.487	1.502	1.517	1.546	1.575	1.604	1.634	1.663	1.692	1.721	1.751	1.780	1.809
39	1.361	1.375	1.389	1.404	1.418	1.432	1.446	1.461	1.475	1.489	1.503	1.532	1.560	1.589	1.617	1.646	1.674	1.703	1.731	1.760	1.788
40	1.352	1.366	1.380	1.394	1.408	1.421	1.435	1.449	1.463	1.477	1.491	1.519	1.546	1.574	1.602	1.630	1.658	1.685	1.713	1.741	1.769
42	1.335	1.348	1.362	1.375	1.388	1.401	1.415	1.428	1.441	1.454	1.467	1.494	1.520	1.547	1.573	1.600	1.626	1.653	1.679	1.706	1.732
44	1.320	1.333	1.345	1.358	1.370	1.383	1.396	1.408	1.421	1.434	1.446	1.471	1.497	1.522	1.547	1.573	1.598	1.623	1.648	1.674	1.699
46	1.306	1.318	1.330	1.342	1.354	1.366	1.379	1.391	1.403	1.415	1.427	1.451	1.475	1.499	1.523	1.548	1.572	1.596	1.620	1.644	1.668
48	1.293	1.305	1.316	1.328	1.340	1.351	1.363	1.374	1.386	1.397	1.409	1.432	1.455	1.479	1.502	1.525	1.548	1.571	1.594	1.617	1.641
50	1.282	1.293	1.304	1.315	1.326	1.337	1.348	1.359	1.370	1.382	1.393	1.415	1.437	1.459	1.482	1.504	1.526	1.548	1.571	1.593	1.615
52	1.271	1.281	1.292	1.303	1.313	1.324	1.335	1.346	1.356	1.367	1.378	1.399	1.420	1.442	1.463	1.484	1.506	1.527	1.549	1.570	1.591
54	1.261	1.271	1.281	1.292	1.302	1.312	1.322	1.333	1.343	1.353	1.364	1.384	1.405	1.425	1.446	1.467	1.487	1.508	1.528	1.549	1.569
56	1.251	1.261	1.271	1.281	1.291	1.301	1.311	1.321	1.331	1.341	1.351	1.370	1.390	1.410	1.430	1.450	1.470	1.490	1.509	1.520	1.549
58	1.243	1.252	1.262	1.271	1.281	1.291	1.300	1.310	1.319	1.329	1.339	1.358	1.377	1.396	1.415	1.434	1.453	1.473	1.492	1.511	1.530
60	1.235	1.244	1.253	1.262	1.272	1.281	1.290	1.299	1.309	1.318	1.327	1.346	1.364	1.383	1.401	1.420	1.438	1.457	1.475	1.494	1.512
65	1.217	1.225	1.234	1.242	1.251	1.259	1.268	1.276	1.285	1.294	1.302	1.319	1.336	1.353	1.370	1.388	1.405	1.422	1.439	1.456	1.473
70	1.201	1.209	1.217	1.225	1.233	1.241	1.249	1.257	1.265	1.273	1.280	1.296	1.312	1.328	1.344	1.360	1.376	1.392	1.408	1.423	1.439
75	1.188	1.195	1.203	1.210	1.217	1.225	1.232	1.240	1.247	1.254	1.262	1.277	1.291	1.306	1.321	1.336	1.351	1.366	1.380	1.395	1.410

TABLE 2—Concluded

VALUES OF A_t/t_S FOR FLAT PANELS WITH Z-SECTION STIFFENERS. $\frac{b_F}{b_W}=0.4$—Concluded.

b_S/t_S \ b_W/t_W	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
										$\frac{t_W}{t_S}=0.79$											
25	1.858	1.893	1.928	1.963	1.998	2.033	2.068	2.103	2.138	2.172	2.207	2.277	2.347	2.417	2.487	2.557	2.627	2.697	2.767	2.836	2.906
26	1.825	1.859	1.892	1.926	1.959	1.993	2.027	2.060	2.094	2.127	2.161	2.228	2.295	2.363	2.430	2.497	2.564	2.631	2.699	2.766	2.833
27	1.794	1.827	1.859	1.891	1.924	1.956	1.989	2.021	2.053	2.086	2.118	2.183	2.247	2.312	2.377	2.442	2.506	2.571	2.636	2.700	2.765
28	1.766	1.797	1.828	1.860	1.891	1.922	1.953	1.984	2.016	2.047	2.078	2.140	2.203	2.265	2.328	2.390	2.453	2.515	2.577	2.640	2.702
29	1.740	1.770	1.800	1.830	1.860	1.890	1.920	1.950	1.981	2.014	2.041	2.101	2.161	2.222	2.282	2.342	2.402	2.463	2.523	2.583	2.643
30	1.715	1.744	1.773	1.802	1.831	1.861	1.890	1.919	1.948	1.977	2.006	2.064	2.123	2.181	2.239	2.297	2.356	2.414	2.472	2.530	2.589
31	1.692	1.720	1.748	1.776	1.805	1.833	1.861	1.889	1.917	1.946	1.974	2.030	2.086	2.143	2.199	2.256	2.312	2.368	2.425	2.481	2.537
32	1.670	1.698	1.725	1.752	1.779	1.807	1.834	1.861	1.889	1.916	1.943	1.998	2.053	2.107	2.162	2.216	2.271	2.326	2.380	2.435	2.489
33	1.650	1.676	1.703	1.729	1.756	1.782	1.809	1.835	1.862	1.888	1.915	1.968	2.021	2.074	2.127	2.179	2.232	2.285	2.338	2.391	2.444
34	1.631	1.657	1.682	1.708	1.734	1.759	1.785	1.811	1.836	1.862	1.888	1.939	1.991	2.042	2.093	2.145	2.196	2.248	2.299	2.350	2.402
35	1.613	1.638	1.663	1.688	1.713	1.738	1.763	1.788	1.812	1.837	1.862	1.912	1.962	2.012	2.062	2.112	2.162	2.212	2.262	2.312	2.362
36	1.596	1.620	1.644	1.669	1.693	1.717	1.741	1.766	1.790	1.814	1.838	1.887	1.936	1.984	2.033	2.081	2.130	2.178	2.227	2.275	2.324
37	1.580	1.603	1.627	1.650	1.674	1.698	1.721	1.745	1.769	1.792	1.816	1.863	1.910	1.957	2.005	2.052	2.099	2.146	2.194	2.241	2.288
38	1.564	1.587	1.610	1.633	1.656	1.679	1.702	1.725	1.748	1.771	1.794	1.840	1.886	1.932	1.978	2.024	2.070	2.116	2.162	2.208	2.254
39	1.550	1.572	1.595	1.617	1.640	1.662	1.684	1.707	1.729	1.752	1.774	1.819	1.864	1.908	1.953	1.998	2.043	2.088	2.132	2.177	2.222
40	1.536	1.558	1.580	1.602	1.624	1.645	1.667	1.689	1.711	1.733	1.755	1.798	1.842	1.886	1.929	1.973	2.017	2.060	2.104	2.148	2.192
42	1.511	1.531	1.552	1.573	1.594	1.615	1.635	1.656	1.677	1.698	1.719	1.760	1.802	1.844	1.885	1.927	1.968	2.010	2.052	2.093	2.135
44	1.487	1.507	1.527	1.547	1.567	1.587	1.607	1.626	1.646	1.666	1.686	1.726	1.765	1.805	1.845	1.885	1.924	1.964	2.004	2.043	2.083
46	1.466	1.485	1.504	1.523	1.542	1.561	1.580	1.599	1.618	1.637	1.656	1.694	1.732	1.770	1.808	1.846	1.884	1.922	1.960	1.998	2.036
48	1.447	1.465	1.483	1.501	1.520	1.538	1.556	1.574	1.592	1.611	1.629	1.665	1.702	1.738	1.774	1.811	1.847	1.884	1.920	1.956	1.993
50	1.429	1.446	1.464	1.481	1.499	1.516	1.534	1.551	1.569	1.586	1.604	1.639	1.674	1.709	1.743	1.778	1.813	1.848	1.883	1.918	1.953
52	1.412	1.429	1.446	1.463	1.480	1.496	1.513	1.530	1.547	1.564	1.580	1.614	1.648	1.681	1.715	1.748	1.782	1.816	1.849	1.883	1.917
54	1.397	1.413	1.430	1.446	1.462	1.478	1.494	1.510	1.527	1.543	1.559	1.591	1.624	1.656	1.688	1.721	1.753	1.786	1.818	1.850	1.883
56	1.383	1.399	1.414	1.430	1.445	1.461	1.477	1.492	1.508	1.523	1.539	1.570	1.601	1.633	1.664	1.695	1.726	1.757	1.789	1.820	1.851
58	1.370	1.385	1.400	1.415	1.430	1.445	1.460	1.475	1.490	1.505	1.520	1.551	1.581	1.611	1.641	1.671	1.701	1.731	1.761	1.792	1.822
60	1.357	1.372	1.387	1.401	1.416	1.430	1.445	1.459	1.474	1.489	1.503	1.532	1.561	1.590	1.620	1.649	1.678	1.707	1.736	1.765	1.794
65	1.330	1.343	1.357	1.370	1.384	1.397	1.411	1.424	1.438	1.451	1.464	1.491	1.518	1.545	1.572	1.599	1.626	1.653	1.679	1.706	1.733
70	1.306	1.319	1.331	1.344	1.356	1.369	1.381	1.394	1.406	1.419	1.431	1.456	1.481	1.506	1.531	1.556	1.581	1.606	1.631	1.656	1.681
75	1.286	1.298	1.309	1.321	1.333	1.344	1.356	1.368	1.379	1.391	1.402	1.426	1.449	1.472	1.496	1.519	1.542	1.566	1.589	1.612	1.635
										$\frac{t_W}{t_S}=1.00$											
25	2.327	2.383	2.439	2.495	2.551	2.607	2.663	2.719	2.775	2.831	2.887	2.999	3.111	3.223	3.335	3.447	3.559	3.761	3.783	3.895	4.007
26	2.276	2.330	2.383	2.437	2.491	2.545	2.599	2.653	2.706	2.760	2.814	2.922	3.030	3.137	3.245	3.353	3.460	3.568	3.676	3.783	3.891
27	2.228	2.280	2.332	2.384	2.436	2.488	2.540	2.591	2.643	2.695	2.747	2.851	2.954	3.058	3.162	3.265	3.369	3.473	3.577	3.680	3.784
28	2.185	2.235	2.285	2.335	2.385	2.435	2.485	2.535	2.585	2.635	2.685	2.785	2.885	2.985	3.085	3.185	3.285	3.385	3.485	3.585	3.685
29	2.144	2.192	2.240	2.289	2.337	2.385	2.433	2.482	2.530	2.578	2.626	2.723	2.820	2.916	3.013	3.109	3.206	3.302	3.399	3.495	3.592
30	2.106	2.152	2.199	2.246	2.292	2.339	2.386	2.432	2.479	2.526	2.572	2.666	2.759	2.852	2.946	3.039	3.132	3.226	3.319	3.412	3.506
31	2.070	2.115	2.160	2.205	2.251	2.296	2.341	2.386	2.432	2.476	2.522	2.612	2.702	2.792	2.883	2.973	3.063	3.154	3.244	3.334	3.425
32	2.036	2.080	2.124	2.168	2.211	2.255	2.299	2.343	2.386	2.430	2.474	2.561	2.649	2.736	2.824	2.911	2.999	3.086	3.174	3.261	3.349
33	2.005	2.048	2.090	2.132	2.175	2.217	2.260	2.302	2.344	2.387	2.429	2.514	2.599	2.684	2.769	2.854	2.938	3.023	3.108	3.193	3.278
34	1.975	2.017	2.058	2.099	2.140	2.181	2.223	2.264	2.305	2.346	2.387	2.470	2.552	2.634	2.717	2.799	2.881	2.964	3.046	3.128	3.211
35	1.948	1.988	2.028	2.068	2.108	2.148	2.188	2.228	2.268	2.308	2.348	2.428	2.508	2.588	2.668	2.748	2.828	2.908	2.988	3.068	3.148
36	1.921	1.960	1.999	2.038	2.077	2.116	2.155	2.194	2.232	2.271	2.310	2.388	2.466	2.544	2.621	2.699	2.777	2.855	2.932	3.010	3.088
37	1.896	1.934	1.972	2.010	2.048	2.086	2.123	2.161	2.199	2.237	2.275	2.350	2.426	2.502	2.578	2.653	2.729	2.805	2.880	2.956	3.032
38	1.873	1.910	1.946	1.983	2.020	2.057	2.094	2.131	2.168	2.204	2.241	2.315	2.389	2.462	2.536	2.610	2.683	2.757	2.831	2.904	2.978
39	1.850	1.886	1.922	1.958	1.994	2.030	2.066	2.102	2.138	2.174	2.209	2.281	2.353	2.425	2.497	2.568	2.640	2.712	2.784	2.856	2.927
40	1.829	1.864	1.899	1.934	1.969	2.004	2.039	2.074	2.109	2.144	2.179	2.249	2.319	2.389	2.459	2.529	2.599	2.669	2.739	2.809	2.879
42	1.790	1.823	1.856	1.890	1.923	1.956	1.990	2.023	2.056	2.090	2.123	2.190	2.256	2.323	2.390	2.456	2.523	2.590	2.656	2.723	2.790
44	1.754	1.786	1.817	1.849	1.881	1.913	1.945	1.976	2.008	2.040	2.072	2.136	2.199	2.263	2.327	2.390	2.454	2.517	2.581	2.645	2.708
46	1.721	1.751	1.782	1.812	1.843	1.873	1.904	1.934	1.964	1.995	2.025	2.086	2.147	2.208	2.269	2.330	2.391	2.451	2.512	2.573	2.634
48	1.691	1.720	1.749	1.778	1.808	1.837	1.866	1.895	1.924	1.953	1.983	2.041	2.099	2.158	2.216	2.274	2.333	2.391	2.449	2.508	2.566
50	1.663	1.691	1.719	1.747	1.775	1.803	1.831	1.859	1.887	1.915	1.943	1.999	2.055	2.111	2.167	2.223	2.279	2.335	2.391	2.447	2.503
52	1.638	1.665	1.692	1.719	1.746	1.772	1.799	1.826	1.853	1.880	1.907	1.961	2.015	2.069	2.122	2.176	2.230	2.284	2.338	2.392	2.446
54	1.614	1.640	1.666	1.692	1.718	1.744	1.770	1.796	1.822	1.848	1.873	1.925	1.977	2.029	2.081	2.133	2.185	2.236	2.288	2.340	2.392
56	1.592	1.617	1.642	1.667	1.692	1.717	1.742	1.767	1.792	1.817	1.842	1.892	1.942	1.992	2.042	2.092	2.142	2.192	2.242	2.292	2.342
58	1.572	1.596	1.620	1.644	1.668	1.693	1.717	1.741	1.765	1.789	1.813	1.861	1.910	1.958	2.006	2.055	2.103	2.151	2.199	2.248	2.296
60	1.553	1.576	1.599	1.623	1.646	1.669	1.693	1.716	1.739	1.763	1.786	1.833	1.879	1.926	1.973	2.020	2.066	2.113	2.160	2.206	2.253
65	1.510	1.532	1.553	1.575	1.596	1.618	1.639	1.661	1.683	1.704	1.726	1.769	1.812	1.855	1.898	1.941	1.984	2.027	2.070	2.113	2.156
70	1.474	1.494	1.514	1.534	1.554	1.574	1.594	1.614	1.634	1.654	1.674	1.714	1.754	1.794	1.834	1.874	1.914	1.954	1.994	2.034	2.074
75	1.442	1.461	1.480	1.498	1.517	1.536	1.554	1.573	1.592	1.610	1.629	1.666	1.704	1.741	1.778	1.816	1.853	1.890	1.928	1.965	2.002

TABLE 3

VALUES OF A_t/t_S FOR FLAT PANELS WITH Z-SECTION STIFFENERS. $\frac{b_F}{b_W}=0.5$.

$$\left[\frac{A_t}{t_S}=1+\frac{\frac{b_W}{t_W}\left(1+\frac{b_F}{b_W}\right)+\frac{b_L}{t_W}-\left(2-\frac{\pi}{2}\right)\left(\frac{r_L}{t_W}+\frac{r_F}{t_W}+1\right)}{b_S/t_S}\left(\frac{t_W}{t_S}\right)^2\right]$$

b_S/t_S \ b_W/t_W	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
									$\frac{t_W}{t_S}=0.51$												
25	1.395	1.411	1.426	1.442	1.457	1.473	1.489	1.504	1.520	1.535	1.551	1.582	1.613	1.645	1.676	1.707	1.738	1.769	1.801	1.832	1.863
26	1.381	1.395	1.410	1.425	1.440	1.455	1.470	1.485	1.500	1.515	1.530	1.760	1.590	1.620	1.650	1.680	1.710	1.740	1.770	1.800	1.830
27	1.366	1.380	1.395	1.409	1.424	1.438	1.452	1.467	1.481	1.496	1.510	1.539	1.568	1.597	1.626	1.655	1.684	1.712	1.741	1.770	1.799
28	1.353	1.367	1.381	1.394	1.408	1.422	1.436	1.450	1.464	1.478	1.492	1.520	1.548	1.576	1.603	1.631	1.659	1.687	1.715	1.743	1.771
29	1.340	1.354	1.367	1.381	1.394	1.408	1.421	1.435	1.448	1.462	1.475	1.502	1.529	1.556	1.583	1.610	1.636	1.663	1.690	1.717	1.744
30	1.329	1.342	1.355	1.368	1.381	1.394	1.407	1.420	1.433	1.446	1.459	1.485	1.511	1.537	1.563	1.589	1.615	1.641	1.667	1.693	1.719
31	1.319	1.331	1.344	1.356	1.369	1.381	1.394	1.407	1.419	1.432	1.444	1.470	1.495	1.520	1.545	1.570	1.595	1.621	1.646	1.671	1.696
32	1.309	1.321	1.333	1.345	1.357	1.370	1.382	1.394	1.406	1.418	1.430	1.455	1.479	1.504	1.528	1.552	1.577	1.601	1.626	1.650	1.674
33	1.299	1.311	1.323	1.335	1.347	1.358	1.370	1.382	1.394	1.406	1.417	1.441	1.465	1.488	1.512	1.536	1.559	1.583	1.607	1.630	1.654
34	1.290	1.302	1.313	1.325	1.336	1.348	1.359	1.371	1.382	1.394	1.405	1.428	1.451	1.474	1.497	1.520	1.543	1.566	1.589	1.612	1.635
35	1.282	1.293	1.304	1.316	1.327	1.338	1.349	1.360	1.371	1.382	1.394	1.416	1.438	1.460	1.483	1.505	1.527	1.550	1.572	1.594	1.616
36	1.274	1.285	1.296	1.307	1.318	1.328	1.339	1.350	1.361	1.372	1.383	1.404	1.426	1.448	1.469	1.491	1.513	1.534	1.556	1.578	1.599
37	1.267	1.277	1.288	1.298	1.309	1.320	1.330	1.341	1.351	1.362	1.372	1.393	1.414	1.436	1.457	1.478	1.499	1.520	1.541	1.562	1.583
38	1.260	1.270	1.280	1.291	1.301	1.311	1.321	1.332	1.342	1.352	1.363	1.383	1.404	1.424	1.445	1.465	1.486	1.506	1.527	1.547	1.568
39	1.253	1.263	1.273	1.283	1.293	1.303	1.313	1.323	1.333	1.343	1.353	1.373	1.393	1.413	1.433	1.453	1.473	1.493	1.513	1.533	1.553
40	1.247	1.257	1.266	1.276	1.286	1.296	1.305	1.315	1.325	1.335	1.344	1.364	1.383	1.403	1.422	1.442	1.461	1.481	1.500	1.520	1.539
42	1.235	1.244	1.254	1.263	1.272	1.282	1.291	1.300	1.309	1.319	1.328	1.347	1.365	1.384	1.402	1.421	1.439	1.458	1.477	1.495	1.514
44	1.224	1.233	1.242	1.251	1.260	1.269	1.278	1.286	1.295	1.304	1.313	1.331	1.349	1.366	1.384	1.402	1.419	1.437	1.455	1.473	1.490
46	1.215	1.223	1.232	1.240	1.249	1.257	1.266	1.274	1.283	1.291	1.299	1.316	1.333	1.350	1.367	1.384	1.401	1.418	1.435	1.452	1.469
48	1.206	1.214	1.222	1.230	1.238	1.246	1.254	1.263	1.271	1.279	1.287	1.303	1.319	1.336	1.352	1.368	1.384	1.401	1.417	1.433	1.450
50	1.197	1.205	1.213	1.221	1.229	1.237	1.244	1.252	1.260	1.268	1.276	1.291	1.307	1.322	1.338	1.354	1.369	1.385	1.400	1.416	1.432
52	1.190	1.197	1.205	1.212	1.220	1.227	1.235	1.242	1.250	1.257	1.265	1.280	1.295	1.310	1.325	1.340	1.355	1.370	1.385	1.400	1.415
54	1.183	1.190	1.197	1.205	1.212	1.219	1.226	1.233	1.241	1.248	1.255	1.270	1.284	1.298	1.313	1.327	1.342	1.356	1.371	1.385	1.400
56	1.176	1.183	1.190	1.197	1.204	1.211	1.218	1.225	1.232	1.239	1.246	1.260	1.274	1.288	1.302	1.316	1.330	1.344	1.357	1.371	1.385
58	1.170	1.177	1.184	1.190	1.197	1.204	1.211	1.217	1.224	1.231	1.237	1.251	1.264	1.278	1.291	1.305	1.318	1.332	1.345	1.359	1.372
60	1.165	1.171	1.178	1.184	1.191	1.197	1.204	1.210	1.217	1.223	1.230	1.243	1.256	1.269	1.282	1.295	1.308	1.321	1.334	1.347	1.360
65	1.152	1.158	1.164	1.170	1.176	1.182	1.188	1.194	1.200	1.206	1.212	1.224	1.236	1.248	1.260	1.272	1.284	1.296	1.308	1.320	1.332
70	1.141	1.147	1.152	1.158	1.163	1.169	1.175	1.180	1.186	1.191	1.197	1.208	1.219	1.230	1.241	1.253	1.264	1.275	1.286	1.297	1.308
75	1.132	1.137	1.142	1.147	1.152	1.158	1.163	1.168	1.173	1.178	1.184	1.194	1.204	1.215	1.295	1.236	1.246	1.256	1.267	1.277	1.288
									$\frac{t_W}{t_S}=0.63$												
25	1.595	1.619	1.642	1.666	1.690	1.714	1.738	1.762	1.785	1.809	1.833	1.881	1.928	1.976	2.024	2.071	2.119	2.166	2.214	2.262	2.309
26	1.572	1.595	1.618	1.641	1.664	1.686	1.709	1.732	1.755	1.778	1.810	1.847	1.893	1.928	1.984	2.030	2.076	2.122	2.167	2.213	2.259
27	1.551	1.573	1.595	1.617	1.639	1.661	1.683	1.705	1.727	1.749	1.771	1.815	1.860	1.904	1.948	1.992	2.036	2.080	2.124	2.168	2.212
28	1.531	1.552	1.574	1.595	1.616	1.637	1.659	1.680	1.701	1.722	1.744	1.786	1.829	1.871	1.914	1.956	1.999	2.042	2.084	2.127	2.169
29	1.513	1.533	1.554	1.574	1.595	1.615	1.636	1.657	1.677	1.698	1.718	1.759	1.800	1.841	1.882	1.923	1.964	2.006	2.047	2.088	2.129
30	1.496	1.516	1.535	1.555	1.575	1.595	1.615	1.635	1.654	1.674	1.694	1.734	1.774	1.813	1.853	1.893	1.932	1.972	2.012	2.051	2.091
31	1.480	1.499	1.518	1.537	1.557	1.576	1.595	1.614	1.633	1.653	1.672	1.710	1.749	1.787	1.825	1.864	1.902	1.941	1.979	2.018	2.056
32	1.465	1.483	1.502	1.521	1.539	1.558	1.576	1.595	1.614	1.632	1.651	1.688	1.725	1.762	1.800	1.837	1.874	1.911	1.949	1.986	2.023
33	1.451	1.469	1.487	1.505	1.523	1.541	1.559	1.577	1.595	1.613	1.631	1.667	1.703	1.739	1.775	1.811	1.848	1.884	1.920	1.956	1.992
34	1.437	1.455	1.472	1.490	1.507	1.525	1.542	1.560	1.578	1.595	1.613	1.648	1.683	1.718	1.753	1.788	1.823	1.858	1.893	1.928	1.963
35	1.425	1.442	1.459	1.476	1.493	1.510	1.527	1.544	1.561	1.578	1.595	1.629	1.663	1.697	1.731	1.765	1.799	1.833	1.867	1.901	1.935
36	1.413	1.430	1.446	1.463	1.479	1.496	1.512	1.529	1.545	1.562	1.578	1.612	1.645	1.678	1.711	1.744	1.777	1.810	1.843	1.876	1.909
37	1.402	1.418	1.434	1.450	1.466	1.482	1.498	1.515	1.531	1.547	1.563	1.595	1.627	1.659	1.692	1.724	1.756	1.788	1.820	1.853	1.885
38	1.391	1.407	1.423	1.438	1.454	1.470	1.485	1.501	1.517	1.532	1.548	1.579	1.611	1.642	1.673	1.705	1.736	1.767	1.799	1.830	1.861
39	1.381	1.397	1.412	1.427	1.442	1.458	1.473	1.488	1.503	1.519	1.534	1.565	1.595	1.626	1.656	1.687	1.717	1.748	1.778	1.809	1.839
40	1.372	1.387	1.402	1.416	1.431	1.446	1.461	1.476	1.491	1.506	1.521	1.550	1.580	1.610	1.640	1.669	1.699	1.729	1.759	1.789	1.818
42	1.354	1.368	1.382	1.397	1.411	1.425	1.439	1.453	1.468	1.482	1.496	1.524	1.553	1.581	1.609	1.638	1.666	1.694	1.723	1.751	1.779
44	1.338	1.352	1.365	1.379	1.392	1.406	1.419	1.433	1.446	1.460	1.473	1.500	1.527	1.554	1.582	1.609	1.636	1.663	1.690	1.717	1.744
46	1.323	1.336	1.349	1.362	1.375	1.388	1.401	1.414	1.427	1.440	1.453	1.479	1.505	1.530	1.556	1.582	1.608	1.634	1.660	1.686	1.712
48	1.310	1.322	1.335	1.347	1.359	1.372	1.384	1.397	1.409	1.421	1.434	1.459	1.483	1.508	1.533	1.558	1.583	1.608	1.632	1.657	1.682
50	1.297	1.309	1.321	1.333	1.345	1.357	1.369	1.381	1.393	1.405	1.417	1.440	1.464	1.488	1.512	1.536	1.559	1.583	1.607	1.631	1.655
52	1.286	1.297	1.309	1.320	1.332	1.343	1.355	1.366	1.378	1.389	1.400	1.423	1.446	1.469	1.492	1.515	1.538	1.561	1.584	1.607	1.629
54	1.275	1.286	1.297	1.308	1.320	1.331	1.342	1.353	1.364	1.375	1.386	1.408	1.430	1.452	1.474	1.496	1.518	1.540	1.562	1.584	1.606
56	1.266	1.276	1.287	1.297	1.308	1.319	1.329	1.340	1.351	1.361	1.372	1.393	1.414	1.436	1.457	1.478	1.499	1.521	1.542	1.563	1.585
58	1.256	1.267	1.277	1.287	1.297	1.308	1.318	1.328	1.339	1.349	1.359	1.380	1.400	1.421	1.441	1.462	1.482	1.503	1.523	1.544	1.564
60	1.248	1.258	1.268	1.278	1.288	1.297	1.307	1.317	1.327	1.337	1.347	1.367	1.387	1.407	1.426	1.446	1.466	1.486	1.506	1.526	1.546
65	1.229	1.238	1.247	1.256	1.265	1.275	1.284	1.293	1.302	1.311	1.320	1.339	1.357	1.375	1.394	1.412	1.430	1.449	1.467	1.485	1.504
70	1.212	1.221	1.229	1.238	1.246	1.255	1.263	1.272	1.281	1.289	1.298	1.315	1.332	1.349	1.366	1.383	1.400	1.417	1.434	1.451	1.468
75	1.198	1.206	1.214	1.222	1.230	1.238	1.246	1.254	1.262	1.270	1.278	1.294	1.309	1.325	1.341	1.357	1.373	1.389	1.405	1.421	1.436

TABLE 3—Concluded

VALUES OF A/t_s FOR FLAT PANELS WITH Z-SECTION STIFFENERS, $\frac{b_F}{b_W}=0.5$—Concluded.

b_s/t_s \ b_W/t_W	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
										$\frac{t_W}{t_s}=0.79$											
25	1.908	1.945	1.983	2.020	2.058	2.095	2.133	2.170	2.207	2.245	2.282	2.357	2.432	2.507	2.582	2.657	2.732	2.807	2.881	2.976	3.031
26	1.873	1.909	1.945	1.981	2.017	2.053	2.089	2.125	2.161	2.197	2.233	2.305	2.377	2.449	2.521	2.593	2.665	2.737	2.809	2.881	2.953
27	1.841	1.875	1.910	1.945	1.979	2.014	2.049	2.083	2.118	2.153	2.187	2.257	2.326	2.395	2.465	2.534	2.603	2.673	2.742	2.811	2.881
28	1.811	1.844	1.877	1.911	1.944	1.978	2.011	2.045	2.078	2.111	2.145	2.212	2.279	2.346	2.412	2.479	2.546	2.613	2.680	2.747	2.814
29	1.783	1.815	1.847	1.879	1.912	1.944	1.976	2.009	2.041	2.073	2.105	2.170	2.235	2.299	2.364	2.428	2.493	2.557	2.622	2.686	2.751
30	1.756	1.788	1.819	1.850	1.881	1.913	1.944	1.975	2.006	2.037	2.069	2.131	2.193	2.256	2.318	2.381	2.443	2.505	2.568	2.630	2.693
31	1.732	1.762	1.793	1.823	1.853	1.883	1.913	1.943	1.974	2.004	2.034	2.095	2.155	2.215	2.276	2.336	2.396	2.457	2.517	2.578	2.638
32	1.709	1.738	1.768	1.797	1.826	1.856	1.885	1.914	1.943	1.973	2.002	2.060	2.119	2.177	2.236	2.294	2.353	2.411	2.470	2.528	2.587
33	1.688	1.716	1.744	1.773	1.801	1.830	1.858	1.886	1.915	1.943	1.971	2.028	2.085	2.142	2.198	2.255	2.312	2.369	2.425	2.482	2.539
34	1.668	1.695	1.723	1.750	1.778	1.805	1.833	1.860	1.888	1.915	1.943	1.998	2.053	2.108	2.163	2.218	2.273	2.328	2.383	2.438	2.494
35	1.648	1.675	1.702	1.729	1.755	1.782	1.809	1.836	1.862	1.889	1.916	1.969	2.023	2.076	2.130	2.183	2.237	2.290	2.344	2.397	2.451
36	1.630	1.656	1.682	1.708	1.734	1.760	1.786	1.812	1.838	1.864	1.890	1.942	1.994	2.047	2.099	2.151	2.203	2.255	2.307	2.359	2.411
37	1.613	1.639	1.664	1.689	1.715	1.740	1.765	1.790	1.816	1.841	1.866	1.917	1.968	2.018	2.069	2.119	2.170	2.221	2.271	2.322	2.372
38	1.597	1.622	1.647	1.671	1.696	1.720	1.745	1.770	1.794	1.819	1.844	1.893	1.942	1.991	2.041	2.090	2.139	2.189	2.238	2.287	2.336
39	1.582	1.606	1.630	1.554	1.678	1.702	1.726	1.750	1.774	1.798	1.822	1.870	1.918	1.966	2.014	2.062	2.110	2.158	2.206	2.254	2.302
40	1.567	1.591	1.614	1.638	1.661	1.684	1.708	1.731	1.755	1.778	1.801	1.848	1.895	1.942	1.989	2.035	2.082	2.129	2.176	2.223	2.270
42	1.540	1.563	1.585	1.607	1.630	1.652	1.674	1.696	1.719	1.741	1.763	1.808	1.852	1.897	1.942	1.986	2.031	2.075	2.120	2.165	2.209
44	1.516	1.537	1.558	1.580	1.601	1.622	1.643	1.665	1.686	1.707	1.729	1.771	1.814	1.856	1.899	1.941	1.984	2.026	2.069	2.112	2.154
46	1.493	1.514	1.534	1.554	1.575	1.595	1.615	1.636	1.656	1.677	1.697	1.738	1.778	1.819	1.860	1.900	1.941	1.982	2.023	2.063	2.104
48	1.473	1.492	1.512	1.531	1.551	1.570	1.590	1.609	1.629	1.648	1.668	1.707	1.746	1.785	1.824	1.863	1.902	1.941	1.980	2.019	2.058
50	1.454	1.473	1.491	1.510	1.529	1.548	1.566	1.585	1.604	1.622	1.641	1.679	1.716	1.753	1.791	1.828	1.866	1.903	1.941	1.978	2.016
52	1.436	1.454	1.472	1.490	1.508	1.526	1.544	1.562	1.580	1.598	1.616	1.652	1.688	1.724	1.760	1.796	1.833	1.869	1.905	1.941	1.977
54	1.420	1.438	1.455	1.472	1.490	1.507	1.524	1.542	1.559	1.576	1.594	1.628	1.663	1.698	1.732	1.767	1.802	1.836	1.871	1.906	1.940
56	1.405	1.422	1.439	1.455	1.472	1.489	1.506	1.522	1.539	1.556	1.572	1.606	1.639	1.673	1.706	1.740	1.773	1.806	1.840	1.873	1.907
58	1.391	1.407	1.424	1.440	1.456	1.472	1.488	1.504	1.520	1.537	1.553	1.585	1.617	1.650	1.682	1.714	1.746	1.779	1.811	1.843	1.875
60	1.378	1.394	1.409	1.425	1.441	1.456	1.472	1.487	1.503	1.519	1.534	1.565	1.597	1.628	1.659	1.690	1.722	1.753	1.784	1.815	1.846
65	1.349	1.364	1.378	1.392	1.407	1.421	1.436	1.450	1.464	1.479	1.493	1.522	1.551	1.580	1.608	1.637	1.666	1.695	1.724	1.752	1.781
70	1.324	1.338	1.351	1.364	1.378	1.391	1.404	1.418	1.431	1.445	1.458	1.485	1.511	1.538	1.565	1.592	1.618	1.645	1.672	1.699	1.725
75	1.303	1.315	1.328	1.340	1.353	1.365	1.377	1.390	1.402	1.415	1.427	1.452	1.477	1.502	1.527	1.552	1.577	1.602	1.627	1.652	1.677
										$\frac{t_W}{t_s}=1.00$											
25	2.407	2.467	2.527	2.587	2.647	2.707	2.767	2.827	2.887	2.947	3.007	3.127	3.247	3.367	3.487	3.607	3.727	3.847	3.967	4.087	4.207
26	2.353	2.410	2.468	2.526	2.583	2.641	2.699	2.756	2.814	2.872	2.930	3.045	3.160	3.276	3.391	3.506	3.622	3.737	3.853	3.968	4.083
27	2.302	2.358	2.414	2.469	2.525	2.580	2.636	2.691	2.747	2.802	2.858	2.969	3.080	3.191	3.302	3.414	3.525	3.636	3.747	3.858	3.969
28	2.256	2.310	2.363	2.417	2.470	2.524	2.577	2.631	2.685	2.738	2.792	2.899	3.006	3.113	3.220	3.327	3.435	3.542	3.649	3.756	3.863
29	2.213	2.264	2.316	2.368	2.420	2.471	2.523	2.575	2.626	2.678	2.730	2.833	2.937	3.040	3.144	3.247	3.351	3.454	3.558	3.661	3.764
30	2.172	2.222	2.272	2.322	2.372	2.422	2.472	2.522	2.572	2.622	2.672	2.772	2.872	2.972	3.072	3.172	3.272	3.372	3.472	3.572	3.672
31	2.134	2.183	2.231	2.280	2.328	2.376	2.425	2.473	2.522	2.570	2.618	2.715	2.812	2.909	3.005	3.102	3.199	3.296	3.392	3.489	3.586
32	2.099	2.146	2.193	2.240	2.286	2.333	2.380	2.427	2.474	2.521	2.568	2.661	2.755	2.849	2.943	3.036	3.130	3.224	3.318	3.411	3.505
33	2.066	2.111	2.157	2.202	2.248	2.293	2.338	2.384	2.429	2.475	2.520	2.611	2.702	2.793	2.884	2.975	3.066	3.157	3.248	3.338	3.429
34	2.034	2.078	2.123	2.168	2.211	2.254	2.299	2.343	2.387	2.431	2.476	2.564	2.652	2.740	2.828	2.917	3.005	3.093	3.181	3.270	3.358
35	2.005	2.048	2.090	2.133	2.176	2.219	2.262	2.305	2.348	2.390	2.433	2.519	2.605	2.690	2.776	2.862	2.948	3.033	3.119	3.205	3.290
36	1.977	2.019	2.060	2.102	2.144	2.185	2.227	2.269	2.310	2.352	2.394	2.477	2.560	2.644	2.727	2.810	2.894	2.977	3.060	3.144	3.227
37	1.950	1.991	2.032	2.072	2.113	2.153	2.194	2.234	2.275	2.315	2.356	2.437	2.518	2.599	2.680	2.761	2.842	2.923	3.005	3.086	3.167
38	1.925	1.965	2.004	2.044	2.083	2.123	2.162	2.202	2.241	2.281	2.320	2.399	2.478	2.557	2.636	2.715	2.794	2.873	2.952	3.031	3.110
39	1.902	1.940	1.979	2.017	2.056	2.094	2.133	2.171	2.209	2.248	2.286	2.363	2.440	2.517	2.594	2.671	2.748	2.825	2.902	2.979	3.056
40	1.879	1.917	1.954	1.992	2.029	2.067	2.104	2.142	2.179	2.217	2.254	2.329	2.404	2.479	2.554	2.629	2.704	2.779	2.854	2.929	3.004
42	1.837	1.873	1.909	1.944	1.980	2.016	2.052	2.087	2.123	2.159	2.195	2.266	2.337	2.409	2.480	2.552	2.623	2.695	2.766	2.837	2.909
44	1.799	1.833	1.867	1.901	1.936	1.970	2.004	2.038	2.072	2.106	2.140	2.208	2.277	2.345	2.413	2.481	2.549	2.617	2.686	2.754	2.822
46	1.764	1.797	1.830	1.862	1.895	1.928	1.960	1.993	2.025	2.058	2.091	2.156	2.221	2.286	2.351	2.417	2.482	2.547	2.612	2.678	2.743
48	1.733	1.764	1.795	1.826	1.858	1.889	1.920	1.951	1.983	2.014	2.045	2.108	2.170	2.233	2.295	2.358	2.420	2.483	2.545	2.608	2.670
50	1.703	1.733	1.763	1.793	1.823	1.853	1.883	1.913	1.943	1.973	2.003	2.063	2.123	2.183	2.243	2.303	2.363	2.423	2.483	2.543	2.603
52	1.676	1.705	1.734	1.763	1.792	1.821	1.849	1.878	1.907	1.936	1.965	2.022	2.080	2.138	2.196	2.253	2.311	2.369	2.426	2.484	2.542
54	1.651	1.679	1.707	1.735	1.762	1.790	1.818	1.846	1.873	1.901	1.929	1.985	2.040	2.096	2.151	2.207	2.262	2.318	2.374	2.429	2.485
56	1.628	1.655	1.682	1.708	1.735	1.762	1.789	1.815	1.842	1.869	1.896	1.949	2.003	2.057	2.110	2.164	2.217	2.271	2.324	2.378	2.432
58	1.606	1.632	1.658	1.684	1.710	1.736	1.761	1.787	1.813	1.839	1.865	1.917	1.968	2.020	2.072	2.124	2.175	2.227	2.279	2.330	2.381
60	1.586	1.611	1.636	1.661	1.686	1.711	1.736	1.761	1.786	1.811	1.836	1.886	1.936	1.986	2.036	2.086	2.136	2.186	2.236	2.286	2.336
65	1.541	1.564	1.587	1.610	1.633	1.656	1.679	1.703	1.726	1.749	1.772	1.818	1.864	1.910	1.956	2.003	2.049	2.095	2.141	2.187	2.233
70	1.502	1.524	1.545	1.567	1.588	1.610	1.631	1.652	1.674	1.695	1.717	1.760	1.802	1.845	1.888	1.931	1.974	2.017	2.060	2.102	2.145
75	1.469	1.489	1.509	1.529	1.549	1.569	1.589	1.609	1.629	1.649	1.669	1.709	1.749	1.789	1.829	1.869	1.909	1.949	1.989	2.029	2.069

TABLE 4

VALUES AND COMPUTATIONS FOR OBTAINING IDEAL DESIGN

[P_i=3.0 kips/in.; c=1]

	Step 1	Step 2				Step 3	Step 4	Step 5		
L (in.)	$\frac{P_i}{L\sqrt{c}}$ $\left(\frac{\text{kips in.}}{\text{in.}}\right)$	$\frac{t_w}{t_s}$	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{A_i}{t_s}$	t_s (in.)	t_w (in.)	b_s (in.)	b_w (in.)
10	0.30	0.51	27	26	[a] 34.0	1.427	[a] 0.0618	[a] 0.0315	[a] 1.67	[a] 0.82
		.63	28	25	35.6	1.602	.0526	.0331	1.47	.83
		.79	29	24	36.7	1.860	.0440	.0348	1.28	.83
		1.00	29	24	37.4	2.337	.0343	.0343	1.00	.82
20	.15	.51	32	32	28.7	1.429	.0732	.0373	2.34	1.19
		.63	33	31	[a] 30.4	1.612	[a] .0612	[a] .0386	[a] 2.02	[a] 1.20
		.79	34	29	31.6	1.862	.0510	.0403	1.73	1.17
		1.00	35	28	32.2	2.268	.0411	.0411	1.44	1.15
30	.10	.51	34	37	25.0	1.457	.0824	.0421	2.80	1.56
		.63	35	35	[a] 27.1	1.640	[a] .0675	[a] .0425	[a] 2.36	[a] 1.49
		.79	37	33	27.8	1.886	.0572	.0452	2.12	1.49
		1.00	38	31	28.6	2.278	.0461	.0461	1.75	1.43

[a] Values indicating designs that approach requirement of t_s=0.064 in.

TABLE 5

VALUES AND COMPUTATIONS FOR OBTAINING PRACTICAL DESIGN BY SHORT METHOD

$\left[P_i=3.0 \text{ kips/in.}; L=20 \text{ in.}; c=1; t_s=0.064 \text{ in.}; \frac{t_w}{t_s}=0.79\right]$

Step 1	Step 2			Step 3	Step 4	Step 5 (For t_s=0.064 in.)			Step 6		Step 7			
$\frac{P_i}{L\sqrt{c}}$ $\left(\frac{\text{kips/in.}}{\text{in.}}\right)$	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{A_i}{t_s}$	t_s (in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{A_i}{t_s}$	P_i (kips/in.)	t_w (in.)	b_s (in.)	b_w (in.)	σ_{cr} (ksi)
0.15	30	30	30.9	2.006	0.0484	43.3	26.1	28.8	1.619	2.98	0.051	2.77	1.33	23.5
	35	30	31.7	1.862	.0508									
	40	28	29.7	1.711	.0590									
	50	26	27.1	1.534	.0722									

TABLE 6

VALUES AND COMPUTATIONS FOR OBTAINING DESIGN FOR MAXIMUM STRUCTURAL EFFICIENCY

$\left[P_i=3.0 \text{ kips/in.}; L=20 \text{ in.}; c=1; t_s=0.064 \text{ in.}; \frac{t_w}{t_s}=0.79\right]$

Step 1	Step 2			Step 3	Step 4	Step 7 (For t_s=0.064 in.)			Step 8		Step 9			
$\frac{P_i}{L\sqrt{c}}$ $\left(\frac{\text{kips/in.}}{\text{in.}}\right)$	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{A_i}{t_s}$	t_s (in.)	$\frac{b_s}{t_s}$	$\frac{b_w}{t_w}$	$\bar{\sigma}_f$ (ksi)	$\frac{A_i}{t_s}$	P_i (kips/in.)	t_w (in.)	b_s (in.)	b_w (in.)	σ_{cr} (ksi)
0.15	20	25	26.4	1.858	0.0612	42.1	25.0	29.0	1.612	2.99	0.051	2.69	1.27	24.6
		30	27.1	1.715	.0646									
		35	27.3	1.613	.0682									
		40	27.8	1.536	.0702									
	25	30	29.9	1.861	.0549									
		35	30.2	1.738	.0572									
		40	29.5	1.645	.0618									
		50	27.1	1.516	.0730									
	30	35	31.7	1.862	.0508									
		40	29.6	1.755	.0578									
		50	26.9	1.604	.0696									
		60	24.5	1.503	.0814									
	40	35	26.2	2.112	.0542									
		40	25.8	1.973	.0589									
		50	23.8	1.778	.0709									
		60	22.6	1.649	.0805									
	50	35	23.2	2.362	.0547									
		40	23.4	2.192	.0584									
		50	22.3	1.953	.0688									
		60	20.7	1.794	.0812									

TABLE 7

TEST DATA ON WHICH DESIGN CHARTS ARE BASED FOR 24S–T ALUMINUM-ALLOY FLAT PANELS WITH LONGITUDINAL Z-SECTION STIFFENERS

$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{b_W}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ $\left(\frac{\text{kips/in.}}{\text{in.}}\right)$	$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{b_W}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ $\left(\frac{\text{kips/in.}}{\text{in.}}\right)$	$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{b_W}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ $\left(\frac{\text{kips/in.}}{\text{in.}}\right)$	$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{b_W}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ $\left(\frac{\text{kips/in.}}{\text{in.}}\right)$
$\frac{t_W}{t_S}=0.51$										$\frac{t_W}{t_S}=0.63$									
25	20	0.4	37.0 33.7 25.2 14.8	0.646 .365 .188 .082	50	25	0.3	25.2 24.7 20.8 15.2	0.430 .241 .140 .070	25	20	0.4	38.9 33.4 24.9 14.3	0.626 .307 .159 .065	50	25	0.3	27.4 25.0 20.6 13.5	0.329 .171 .099 .047
	25	.4	36.3 33.8 26.0 15.6	.550 .298 .159 .066			.4	25.9 24.0 22.2 13.6	.431 .217 .144 .061		25	.4	38.9 32.4 24.8 14.2	.517 .242 .132 .054			.4	28.0 25.0 20.4 13.5	.323 .168 .094 .044
	30	.4	33.8 31.3 26.0 15.4	.442 .227 .131 .056			.5	26.5 24.9 22.8 15.9	.403 .217 .140 .069		30	.4	36.3 30.9 24.6 16.6	.420 .199 .113 .055			.5	28.0 26.2 23.0 17.2	.365 .183 .117 .063
	40	.4	29.3 23.9 22.5 16.8	.295 .137 .090 .048		30	.3	25.6 24.3 22.6 15.7	.355 .192 .123 .061		40	.4	29.4 24.2 23.5 15.6	.275 .131 .088 .042		30	.3	26.0 24.9 22.9 16.3	.279 .152 .097 .049
	50	.4	25.9 20.5 17.7 16.4	.222 .101 .061 .049			.4	25.0 23.8 22.6 16.4	.323 .176 .117 .060		50	.4	25.2 22.1 18.7 ----	.210 .104 .061 ----			.4	25.8 26.9 23.2 16.2	.266 .167 .095 .048
35	20	.3	31.5 30.6 25.6 14.9	.644 .358 .211 .088			.5	25.5 24.4 23.0 16.5	.321 .174 .116 .059	35	20	.3	32.0 32.8 25.4 15.6	.516 .304 .168 .072			.5	26.2 24.0 22.3 17.1	.261 .135 .088 .049
		.4	31.2 31.2 25.8 15.2	.611 .347 .203 .086		40	.4	23.3 22.2 20.2 15.7	.219 .118 .078 .041			.4	33.5 34.0 28.3 15.4	.524 .306 .179 .069		40	.4	23.8 22.4 21.4 17.4	.187 .101 .067 .040
		.5	31.4 30.3 26.4 13.4	.587 .325 .202 .073		50	.4	21.3 19.1 18.0 15.6	.159 .080 .054 .037			.5	33.5 32.0 29.4 17.7	.506 .275 .178 .075		50	.4	21.5 19.6 17.9 16.9	.141 .071 .046 .037
	25	.3	32.5 31.7 26.6 16.8	.533 .295 .171 .078	75	20	.3	22.4 18.4 16.5 12.2	.591 .252 .158 .084		25	.3	33.1 32.4 24.7 14.4	.430 .243 .127 .053	75	20	.3	22.0 20.2 15.8 13.0	.381 .206 .110 .065
		.4	30.9 31.2 26.9 13.4	.477 .278 .169 .060			.4	20.5 19.2 16.7 12.0	.471 .245 .149 .078			.4	33.8 32.4 26.1 15.1	.419 .235 .130 .055			.4	22.7 21.3 17.2 12.5	.374 .200 .113 .059
		.5	32.3 31.4 27.0 14.4	.486 .271 .163 .062			.5	21.2 18.6 17.2 13.3	.454 .227 .148 .085			.5	32.5 30.9 28.2 17.4	.429 .238 .158 .068			.5	22.4 20.5 18.5 13.9	.372 .181 .114 .064
	30	.3	31.4 30.7 27.0 16.8	.427 .235 .145 .064		25	.3	21.0 18.6 16.5 13.7	.378 .191 .118 .069		30	.3	30.7 29.9 27.9 17.9	.335 .186 .122 .055		25	.3	22.7 19.2 15.6 12.1	.281 .134 .076 .043
		.4	30.7 31.0 27.4 17.4	.391 .227 .141 .064			.4	21.0 19.4 17.5 12.2	.360 .189 .121 .059			.4	30.7 31.4 28.1 18.5	.329 .193 .121 .057			.4	22.1 19.8 16.4 11.3	.257 .132 .076 .038
		.5	31.1 30.3 27.5 17.5	.392 .242 .138 .062			.5	20.9 19.4 17.6 12.8	.343 .182 .115 .061			.5	30.4 29.1 27.6 18.0	.314 .173 .115 .054			.5	22.7 20.9 18.1 13.8	.304 .161 .097 .053
	40	.4	26.5 25.6 23.6 16.8	.252 .142 .091 .046		30	.3	19.9 18.8 16.4 13.6	.289 .155 .094 .055		40	.4	27.8 24.9 23.8 16.9	.235 .118 .080 .042		30	.3	20.6 19.6 18.6 13.8	.226 .121 .081 .043
	50	.4	23.9 21.8 20.8 16.0	.183 .079 .066 .042			.4	19.1 19.8 17.7 13.4	.268 .156 .098 .053		50	.4	24.0 21.9 19.2 ----	.173 .089 .054 ----			.4	21.2 21.0 18.8 14.1	.219 .128 .079 .042
50	20	.3	26.2 24.0 21.9 15.0	.577 .300 .193 .092			.5	20.6 19.8 17.0 13.2	.272 .148 .089 .049	50	20	.3	28.2 25.0 21.8 15.1	.459 .233 .144 .071			.5	21.0 20 2 18.0 14.2	.207 .121 .075 .040
		.4	26.7 25.1 21.2 14.6	.557 .297 .177 .087		40	.4	19.2 17.9 16.8 12.8	.186 .100 .065 .035			.4	28.3 25.8 22.2 14.5	.447 .230 .140 .065		40	.4	18.6 18.2 17.5 13.4	.138 .081 .053 .029
		.5	26.3 23.7 21.1 15.0	.531 .266 .170 .086		50	.4	17.0 16.2 14.9 11.7	.129 .070 .046 .025			.5	27.4 25.5 22.9 16.3	.410 .216 .137 .069		50	.4	17.7 17.5 16.0 13.1	.105 .061 .039 .024

TABLE 7—Concluded

TEST DATA ON WHICH DESIGN CHARTS ARE BASED FOR 24S-T ALUMINUM-ALLOY FLAT PANELS WITH LONGITUDINAL Z-SECTION STIFFENERS—Concluded

$\frac{t_W}{t_S}=0.79$

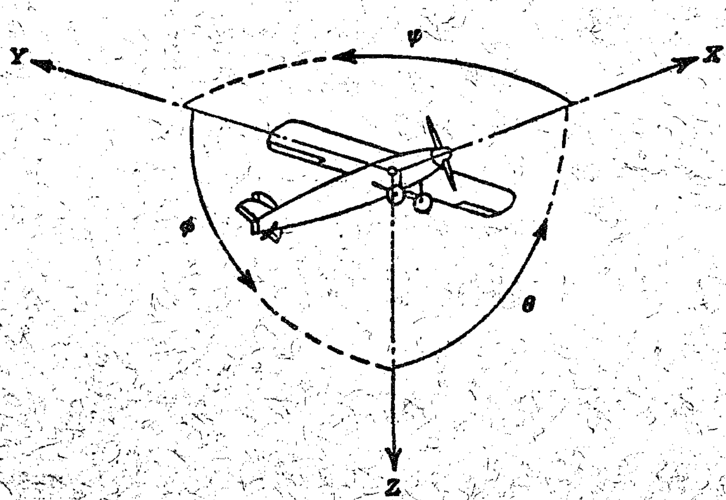
$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{b_W}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (kips/in. / in.)
35	20	0.3	34.5	0.470
			34.4	.270
			26.9	.148
			16.5	.063
		.4	35.7	.472
			34.6	.265
			29.7	.157
			16.8	.062
		.5	34.8	.449
			33.7	.249
			27.7	.141
			17.6	.065
	25	.3	37.0	.394
			32.6	.202
			28.2	.126
			17.6	.056
		.4	35.2	.374
			33.3	.204
			29.3	.123
			17.1	.052
		.5	33.2	.357
			33.8	.213
			17.7	.056
	30	.3	33.8	.340
			32.0	.181
			28.5	.110
			18.6	.052
		.4	32.5	.313
			31.7	.173
			28.2	.107
			17.5	.048
		.5	31.2	.302
			30.2	.162
			26.5	.101
			17.1	.046
50	20	.3	28.7	.369
			27.2	.205
			23.4	.123
			16.2	.061
		.4	29.6	.374
			27.2	.194
			23.2	.115
			16.4	.059
		.5	29.7	.365
			28.5	.201
			23.1	.112
			16.4	.082
	25	.3	28.9	.295
			28.2	.165
			24.4	.100
			16.9	.049
		.4	29.2	.277
			27.8	.158

$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{b_W}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (kips/in. / in.)
50	25	0.4	23.3	0.092
			17.0	.048
		.5	28.5	.309
			27.4	.169
			23.5	.102
			17.2	.053
	30	.3	27.8	.250
			26.6	.137
			23.6	.084
			17.6	.044
		.4	27.6	.238
			26.8	.134
			22.6	.079
			17.2	.043
		.5	26.9	.234
			25.0	.122
			23.7	.084
			16.5	.010
75	20	.3	22.9	.306
			21.7	.167
			17.4	.092
			12.7	.049
		.4	24.7	.313
			23.1	.168
			20.4	.106
			14.2	.052
		.5	24.2	.298
			22.3	.157
			19.4	.094
			13.3	.046
	25	.3	....	....
			22.2	.125
			19.3	.077
			13.8	.040
		.4	24.4	.236
			22.6	.125
			19.5	.075
			13.4	.037
		.5	23.6	.242
			22.9	.137
			19.9	.083
			14.2	.041
	30	.3	22.9	.199
			22.3	.109
			19.2	.066
			14.4	.035
		.4	23.6	.198
			21.6	.102
			19.7	.067
			14.0	.033
		.5	22.5	.182
			20.9	.095
			18.9	.061
			14.8	.037

$\frac{t_W}{t_S}=1.00$

$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{b_W}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (kips/in. / in.)
35	20	0.3	36.3	0.430
			32.8	.215
			26.8	.123
			17.6	.059
		.4	36.7	.418
			33.7	.222
			27.3	.122
			17.5	.057
		.5	36.1	.414
			34.1	.223
			28.0	.130
			17.2	.057
	25	.3	33.5	.333
			31.7	.180
			27.3	.108
			18.1	.052
		.4	35.4	.347
			31.8	.177
			28.7	.112
			16.4	.047
		.5	35.3	.358
			33.1	.190
			25.3	.103
			16.8	.048
	30	.3	33.1	.290
			29.4	.149
			23.6	.084
			15.0	.037
		.4	33.3	.291
			31.6	.163
			23.8	.083
			15.1	.038
		.5	32.7	.300
			30.1	.160
			26.0	.095
			13.5	.036
50	20	.3	30.2	.320
			27.8	.165
			23.2	.096
			18.5	.051
		.4	31.6	.322
			29.1	.167
			24.1	.096
			16.7	.048
		.5	32.0	.326
			28.2	.164
			23.2	.092
			16.5	.049
	25	.3	29.6	.260
			27.1	.134
			24.3	.084
			17.2	.042
		.4	31.0	.262
			27.7	.138

$\frac{b_S}{t_S}$	$\frac{b_W}{t_W}$	$\frac{b_F}{b_W}$	$\bar{\sigma}_f$ (ksi)	$\frac{P_i}{L/\sqrt{c}}$ (kips/in. / in.)
50	25	0.4	21.5	0.083
			18.0	.046
		.5	30.8	.270
			27.9	.139
			23.9	.084
			17.5	.044
	30	.3	28.2	.213
			25.9	.112
			23.3	.070
			16.6	.037
		.4	29.0	.218
			27.5	.120
			21.8	.065
			16.6	.036
		.5	28.1	.216
			26.3	.117
			22.7	.070
			16.1	.036
75	20	.3	24.0	.235
			23.2	.129
			18.3	.072
			14.6	.041
		.4	25.9	.245
			23.8	.128
			20.1	.076
			14.3	.039
		.5	26.1	.250
			24.7	.129
			20.2	.077
			14.8	.041
	25	.3	24.2	.200
			22.4	.101
			20.7	.066
			14.7	.033
		.4	25.8	.199
			24.1	.106
			21.1	.065
			14.3	.033
		.5	25.5	.199
			23.9	.108
			21.5	.067
			14.1	.032
	30	.3	23.9	.161
			21.6	.084
			19.6	.053
			14.5	.028
		.4	24.2	.160
			22.8	.086
			20.8	.056
			14.8	.028
		.5	24.0	.163
			22.4	.086
			20.2	.055
			14.1	.027



Positive directions of axes and angles (forces and moments) are shown by arrows

Axis: Designation	Axis: Symbol	Force (parallel to axis) symbol	Moment about axis: Designation	Moment about axis: Symbol	Moment about axis: Positive direction	Angle: Designation	Angle: Symbol	Velocities: Linear (component along axis)	Velocities: Angular
Longitudinal	X	X	Rolling	L	$Y \longrightarrow Z$	Roll	ϕ	u	p
Lateral	Y	Y	Pitching	M	$Z \longrightarrow X$	Pitch	θ	v	q
Normal	Z	Z	Yawing	N	$X \longrightarrow Y$	Yaw	ψ	w	r

Absolute coefficients of moment

$C_l=\frac{L}{qbS}$ (rolling) $C_m=\frac{M}{qcS}$ (pitching) $C_n=\frac{N}{qbS}$ (yawing)

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D Diameter

p Geometric pitch

p/D Pitch ratio

V' Inflow velocity

V_s Slipstream velocity

T Thrust, absolute coefficient $C_T=\frac{T}{\rho n^2 D^4}$

Q Torque, absolute coefficient $C_Q=\frac{Q}{\rho n^2 D^5}$

P Power, absolute coefficient $C_P=\frac{P}{\rho n^3 D^5}$

C_s Speed-power coefficient $=\sqrt[5]{\frac{\rho V^5}{P n^2}}$

η Efficiency

n Revolutions per second, rps

Φ Effective helix angle $=\tan^{-1}\left(\frac{V}{2\pi r n}\right)$

5. NUMERICAL RELATIONS

1 hp=76.04 kg-m/s=550 ft-lb/sec

1 metric horsepower=0.9863 hp

1 mph=0.4470 mps

1 mps=2.2369 mph

1 lb=0.4536 kg

1 kg=2.2046 lb

1 mi=1,609.35 m=5,280 ft

1 m=3.2808 ft